N60028_000125
TREASURE ISLAND
SSIC NO. 5090.3.C

COMPREHENSIVE LONG-TERM ENVIRONMENTAL ACTION NAVY
Northern and Central California, Nevada, and Utah
Contract No. N62474-94-D-7609
Contract Task Order 314

Prepared for

DEPARTMENT OF THE NAVY
Jim Sullivan, Remedial Project Manager
Southwest Division
Naval Facilities Engineering Command
San Diego, California

DRAFT FIELD SAMPLING PLAN ADDENDUM INSTALLATION AND SAMPLING OF ADDITIONAL GROUNDWATER MONITORING WELLS INSTALLATION RESTORATION SITE 12 NAVAL STATION TREASURE ISLAND SAN FRANCISCO, CALIFORNIA

DS.0314.15091

January 17, 2001

Prepared By

Tetra Tech EM Inc.
135 Main Street, Suite 1800
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Kevin Hoch

Kevin Hoch
Project Manager

DRAFT FIELD SAMPLING PLAN ADDENDUM

INSTALLATION AND SAMPLING OF ADDITIONAL GROUNDWATER MONITORING WELLS INSTALLATION RESTORATION SITE 12

NAVAL STATION TREASURE ISLAND SAN FRANCISCO, CALIFORNIA

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Prepared for

U.S. DEPARTMENT OF THE NAVY

REVIEW AND APPROVALS

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Navy Quality Assurance Officer: Narciso Ancog Date: 1/17/01
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TETRA TECH EM INC.

TRANSMITTAL/DELIVERABLE RECEIPT

Contract No. N62474-94-D-7609 Document Control No. DS . 0314 . 15091

TO: Mr. Richard Selby, Code 02R1
Contracting Officer
Naval Facilities Engineering Command
Southwest Division
1230 Columbia Street, Suite 1100
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DATE: 01/22/01
CTO: 0314
LOCATION:
NAVSTA Treasure Island, San Francisco

FROM:
Daniel Chow, Program Manager

DOCUMENT TITLE AND DATE:

Draft Field Sampling Plan Addendum; Installation and Sampling of Additional Groundwater Monitoring Wells; Installation Restoration Site 12; January 17, 2001

TYPE: ☐ Contractual Deliverable ☒ Technical Deliverable ☐ Other

VERSION: Draft (e.g., Draft, Draft Final, Final) REVISION #: NA

ADMIN RECORD: Yes ☒ No ☐ CATEGORY: Confidential ☐

SCHEDULED DELIVERY DATE: NA ACTUAL DELIVERY DATE: 01/22/01

NUMBER OF COPIES SUBMITTED TO NAVY: O/6C/7E

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January 22, 2001

Mr. Jim Sullivan (Code 06CA.JS)
Remedial Project Manager
Southwest Division
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Subject: **Draft Field Sampling Plan Addendum for Installation and Sampling of Additional Groundwater Monitoring Wells at Installation Restoration Site 12 Naval Station Treasure Island, San Francisco, California CLEAN II Contract No. N62474-94-D-7609, Contract Task Order 314**

Dear Mr. Sullivan:

Tetra Tech EM Inc. (TtEMI) is pleased to submit a copy of the draft field sampling plan (FSP) addendum for installation and sampling of additional groundwater monitoring wells at installation restoration Site 12.

In addition to the copy in this transmittal, twelve copies of the addendum have been forwarded to individuals as specified in the Navy transmittal/deliverable receipt (copy attached).

If you have any questions regarding this submittal, please do not hesitate to call me at (415) 222-8304.

Sincerely,

Kevin Hoch

Kevin Hoch
Project Manager

Enclosures

cc: Victor Early, TtEMI (letter only)
File

DS.0314.15091

DRAFT
FIELD SAMPLING PLAN
INSTALLATION AND SAMPLING OF ADDITIONAL GROUNDWATER MONITORING WELLS
INSTALLATION RESTORATION SITE 12

THIS DOCUMENT WAS NOT RECEIVED IN THE RESTORATION RECORDS FILE.

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ACRONYMS AND ABBREVIATIONS

AWQC	Ambient Water Quality Criteria
bgs	Below ground surface
CLP	Contract laboratory program
CLEAN II	Comprehensive Long-term Environmental Action Navy
CTO	Contract task order
CTR	California Toxics Rule
DPW	Department of Public Works
DQO	Data quality objective
EPA	U.S. Environmental Protection Agency
FS	Feasibility study
FSP	Field sampling plan
IDW	Investigation-derived waste
MLLW	Mean lowest low water
MS/MSD	Matrix spike/matrix spike duplicate
NAVSTA TI	Naval Station Treasure Island
Navy	U.S. Department of the Navy
PCB	Polychlorinated biphenyl
PRC	PRC Environmental Management, Inc.
PVC	Polyvinyl chloride
QAPP	Quality assurance project plan
QA/QC	Quality assurance/quality control
QC	Quality control
RI	Remedial investigation
SFRA	San Francisco Redevelopment Agency
Site 12	Installation Restoration Site 12
SOP	Standard operating procedure
SVOC	Semi-volatile organic compound
SWDIV	Southwest Division
TI	Treasure Island
TPH	Total petroleum hydrocarbons
TPH-e	Total petroleum hydrocarbons as extractable

TtEMI	Tetra Tech EM Inc.
VOC	Volatile organic compound
YBI	Yerba Buena Island

1.0 INTRODUCTION

Tetra Tech EM Inc. (TtEMI), formerly known as PRC Environmental Management, Inc. (PRC), received Contract Task Order (CTO) No. 314 under the Comprehensive Long-term Environmental Action Navy II Contract No. N62474-94-D-7609 (CLEAN II) from the U.S. Department of the Navy (Navy), Naval Facilities Engineering Command, Southwest Division (SWDIV). This CTO directs TtEMI to prepare a work plan to further investigate groundwater at three Areas of Concern at Installation Restoration Site 12 (Site 12) at Naval Station Treasure Island (NAVSTA TI), San Francisco, California.

The purpose of the work described in this work plan is to complete a system of groundwater monitoring wells that will provide groundwater quality data in locations that are downgradient from potential areas of contamination in Site 12. Four groundwater monitoring wells will be installed in locations that are downgradient from Debris Disposal Areas A and B to address gaps in the existing monitoring well network. One of the four monitoring wells will replace a well that may have been damaged during soil excavation activities near Building 1133. The existing groundwater monitoring well network has sufficient coverage to obtain representative groundwater quality data for remaining debris disposal areas in Site 12. In addition, the Navy will install a fifth well near Building 1108 that will be downgradient from an area of elevated polychlorinated biphenyls (PCBs) in the soil below a depth of four feet below ground surface (bgs) in the Halyburton Court area. Groundwater monitoring wells will provide additional groundwater quality and hydrogeologic data to further characterize the nature and extent of potential chemicals of concern in groundwater.

2.0 PURPOSE AND OBJECTIVES

The objective of the sampling proposed in this field sampling plan (FSP) is to obtain groundwater quality data from locations that are downgradient of debris disposal areas in Site 12. Data quality objectives (DQO) for the proposed investigation are described below and presented in Table 1. DQOs specify the level of uncertainty that a decision-maker is willing to accept in results derived from environmental data collection activities. DQOs ascertain the type, quality, and quantity of data necessary to address the problem before sampling and analysis begin. The U.S. Environmental Protection Agency (EPA) guidance document, QA-G4 (EPA 1994), outlines the following seven-step process for establishing DQOs:

- **Step 1 - State the Problem.** Concisely describe the problem to be studied.
- **Step 2 - Identify the Decision.** Identify what questions the study will attempt to resolve and what actions may result.
- **Step 3 - Identify Inputs to the Decision.** Identify the information needed and the resulting measurements that need to be made in order to support the decision.
- **Step 4 - Define the Study Boundaries.** Specify the conditions (time periods, spatial areas, and situations) to which the decision will apply and within which the data will be collected.
- **Step 5 - Develop Decision Rules.** Define the conditions by which the decision-maker will choose among alternative risk management actions. This is usually specified in the form of an "if...then..." statement.
- **Step 6 - Specify Acceptable Limits on Decision Errors.** Define in statistical terms the decision-maker's acceptable error rate based on the consequence of making an incorrect decision.
- **Step 7 - Optimize the Sampling Design.** Evaluate the results of the previous steps and develop the most resource-efficient design for data collection that meets all of the DQOs.

2.1 DATA QUALITY OBJECTIVE STEP 1: STATE THE PROBLEM

The purpose of this step is to describe the problem. The information collected for this step should provide a solid foundation upon which the remainder of the DQO process will be built.

Problem Description

The problem is to determine, through the use of a network of groundwater monitoring wells, whether contamination is migrating from debris areas toward San Francisco Bay and whether any contamination that may be present poses an ecological risk.

2.2 DATA QUALITY OBJECTIVE STEP 2: IDENTIFY THE DECISION

The purpose of this step is to define the decision statement that combines key questions the study will attempt to resolve with the alternative actions that may be taken. The following question needs to be answered to proceed with the DQO process:

- Are contaminants present in groundwater downgradient from Debris Disposal Areas A and B or Building 1133 at concentrations that pose a potential risk to ecological receptors?

2.3 DATA QUALITY OBJECTIVE STEP 3: IDENTIFY INPUTS TO THE DECISION

The purpose of this step is to identify informational inputs needed to support the decision statement and to specify which inputs will require environmental measurements. This information is necessary so that the proper data may be collected to resolve the decision statement. The inputs required to support the decision are from the following sources:

- Site history, including aerial photographs
- Existing chemical data
- Validated, defensible chemical data for groundwater from proposed locations
- Screening criteria for groundwater

2.4 DATA QUALITY OBJECTIVE STEP 4: DEFINE THE STUDY BOUNDARIES

The purpose of this step is to define the site characteristics in terms of spatial boundaries that the environmental measurements are intended to represent. The environmental measurements are defined by the population of interest. The spatial boundaries of the sites are those that define the area to be studied and where samples should be collected. The study boundaries consist of the following:

- The horizontal boundary of the study area is the site boundary for Site 12.
- The vertical boundary of the study area is a depth of 15 feet bgs, which is the depth to which the monitoring wells will be drilled.

2.5 DATA QUALITY OBJECTIVE STEP 5: DEVELOP DECISION RULES

A decision rule is an "if...then" statement that defines the conditions that will cause the decision-makers to choose among alternative actions. Elements that go into developing a decision rule include the following: specification of the parameters that characterize the population of interest, specification of the action levels for the decision, and verification that the action levels exceed the analytical method detection limits. The decision rule for this study is as follows:

- If any chemicals are detected in groundwater at concentrations exceeding applicable groundwater quality criteria, then further investigation or monitoring will be considered. If no chemicals are detected in groundwater at concentrations exceeding applicable water quality criteria, then no further investigation and limited groundwater monitoring will be conducted. The applicable water quality criteria include EPA Ambient Water Quality Criteria (AWQC) for Protection of Saltwater Aquatic Life, criteria from the California Toxics Rule (CTR), or other criteria for protection of marine life if no AWQC or criteria from the CTR are available. For metals, ambient levels are used if the ambient levels are greater than the most conservative criteria for protection of aquatic life.

2.6 DATA QUALITY OBJECTIVE STEP 6: SPECIFY ACCEPTABLE LIMITS ON DECISION ERRORS

Data from this investigation may be strongly indicative of site conditions, but not absolutely definitive; therefore, decisions based on the data could be in error. This is known as the decision error. This step discusses the limits on decision errors for this investigation.

2.6.1 Background

The following two types of errors are associated with data collection and may lead to decision error:

- **Sampling error** occurs, because it is impossible for a sampling effort to measure conditions at every point of a site or at every point in time. Sampling error occurs when the sample is not representative of true conditions of the environment at a site.
- **Measurement error** occurs because of the random and systematic errors associated with sample collection, handling, preparation, analysis, data reduction, and data handling. Measurement error is minimized by close adherence to sampling procedures and application of the January 7, 2000, Draft Quality Assurance Project Plan (QAPP) for Installation Restoration Site 12 Additional Characterization (TtEMI 2000).

These errors may lead to incorrect decisions or recommendations. In general, decision errors are controlled by adopting a scientific approach that minimizes the potential for decision errors through the use of hypothesis testing. EPA guidance (1994) suggests the following steps to identify and control decision errors:

- Define the possible range of the parameter of interest.
- Define both types of decision error and the consequences of each.
- Specify a range of parameter values for which the consequences of decision errors are relatively minor.

Check the limits on decision errors to ensure that they accurately reflect the decision-maker's concerns about the relative consequences for each type of decision error.

2.6.2 Hypothesis and Types of Decision Errors

Decision errors are evaluated through hypothesis testing. The general hypothesis used in this study will be as follows: the physical and chemical tests selected are appropriate to determine whether contaminants are present in groundwater at levels that pose a risk to ecological receptors within the investigation area. There are two types of decision errors, as follows:

- **False negative error** occurs when the hypothesis is rejected when it is, in fact, true. In the case of this investigation, the decision-maker determines that chemicals are not present at levels that pose a risk to ecological receptors based on the results of the analytical data, when in fact, chemicals are present at levels that pose a risk to ecological receptors.

- **False positive error** occurs when the hypothesis is not rejected when it is false. In the case of this investigation, the decision-maker determines that chemicals are present at levels that pose a risk to ecological receptors based on the results of the analytical data, when in fact, chemicals are not present at levels that pose a risk to ecological receptors.

The consequences of a false negative error are that the potential ecological risks of a site will not be evaluated. The consequences of a false positive error are that unnecessary resources are spent to evaluate the site through additional sampling.

2.6.3 Acceptable Error

For this investigation, proposed sampling locations were selected based on previous chemical data in soil. Because of this judgmental sampling approach, limits on decision errors cannot be specified. False positive and false negative error is minimized by adherence to selected sampling and analytical methods. Details of the sampling and analysis methods are outlined in Draft QAPP for Installation Restoration Site 12 Additional Characterization (TtEMI 2000).

2.7 DATA QUALITY OBJECTIVE STEP 7: OPTIMIZE THE SAMPLING DESIGN

The purpose of this step is to identify a resource-effective design for generating environmental data that will satisfy DQOs discussed in previous sections. The sampling design will be optimized in the following way:

- Monitoring wells will be installed at four locations downgradient from debris disposal areas.

- Groundwater samples will be collected at each of the four locations no sooner than 24 hours following well development.

- All samples will be analyzed for metals, total petroleum hydrocarbons (TPH), semivolatile organic compounds (SVOC), volatile organic compounds (VOC), and PCBs.

3.0 BACKGROUND

This section describes site location, background, and previous investigations performed at Site 12.

3.1 SITE LOCATION AND BACKGROUND

NAVSTA TI is in San Francisco Bay, midway between San Francisco and Oakland, California. The facility consists of two contiguous islands: Treasure Island (TI), which is about 403 acres, and Yerba Buena Island (YBI), which is about 147 acres.

TI was built on Yerba Buena Shoals and a sand spit extending from the northwestern point of YBI. Dredging and construction of the island began in 1936 and were completed in 1937. The fill used for construction consisted primarily of sand, with lesser amounts of silt, clay, and gravel. The island was developed to be the site for the 1939 Golden Gate International Exposition and subsequently, San Francisco's commercial airport. NAVSTA TI was closed on September 30, 1997, under the Base Closure and Realignment Act III, and is in the process of being turned over to the City and County of San Francisco. The Navy initiated a gradual reduction of personnel and activities before the closure date.

Site 12 is located on the northern portion of TI and includes areas of housing that the City of San Francisco is leasing or plans to lease in the future. The Navy has performed remedial investigation (RI) activities at Site 12 in 1996 (PRC 1997) and 1998 (TtEMI 1999a, 1999b). From the 1940s to the 1960s, ammunition was stored in bunkers within the site. Soil trenching and boring activities performed before 1965 housing foundation excavations indicate that the areas between and around the bunkers were used for debris disposal. Based on previous reports, historical information on Site 12 indicates that at least four distinct disposal areas are known (PRC 1997).

3.2 GEOLOGY AND HYDROLOGY

TI consists primarily of sand dredged from San Francisco Bay and retained by a perimeter of rock and sand dikes. Various units of Bay Mud sediments are beneath the Yerba Buena Shoals sand, consisting of clays and silty clays with interbedded sand and silt layers, and sandy, silty, and peaty clays. Beneath the

Bay Mud sediments, at an estimated 150 feet to 320 feet bgs, is the Franciscan Assemblage, consisting of interbedded shales and sandstones.

Groundwater at TI is encountered at an average depth of about 5 feet bgs. Groundwater flow is generally radial from the center of the island toward the shoreline, at average gradients ranging from 0.0015 to 0.005 (PRC 1997). Groundwater fluctuation caused by tidal influence ranges from approximately 1.8 feet at near-shore locations to little or no fluctuation at inland locations. Groundwater also fluctuates seasonally.

3.3 PREVIOUS SITE INVESTIGATIONS

Site 12 has been investigated over the years to assess the nature and extent of potential soil and groundwater contamination near debris disposal areas and other known or suspected areas of contamination. Soil and groundwater samples were collected in the vicinity of suspected sources to delineate the extent of localized contamination (PRC 1997). The objectives of these investigations were developed based on the land use assumptions in the City of San Francisco's original reuse plan (San Francisco Redevelopment Agency [SFRA] 1996). The original reuse plan designated future use of Site 12 as a wetland area or recreational park. Subsequently, the reuse plan was revised, which designated the Site 12 area for residential use (SFRA 1996). With this revision to the reuse plan, it was assumed that greater potential for exposure to site contamination may exist under the residential land use scenario. Therefore, additional characterization of Site 12 was conducted in 1997 (Geomatrix 1998) and 1998 (TtEMI 1999a, 1999b). The areas identified as Debris Disposal Areas A and B were further investigated in a Geoprobe® and soil gas investigation in June 1999, a test pit investigation in January 2000, and further soil gas investigations in June 2000. The area near Building 1133 was further investigated in a test pit and soil gas investigation in August and September 1999, which led to a removal action in September 1999. Based on these earlier investigations, additional groundwater quality data gaps were recently identified at Debris Disposal Areas A and B and near the area where soil was excavated behind Building 1133.

4.0 FIELD METHODS AND PROCEDURES

All field activities for this project will follow the methods and protocols detailed in this FSP, the Draft QAPP for Installation Restoration Site 12 Additional Characterization (TtEMI 2000) dated January 7, 2000, and the attached standard operating procedures (SOPs) (see Appendices A, B, and C). Field activities will also be conducted in accordance with TtEMI's CLEAN II program health and safety plan, revision I (PRC 1995) and the NAVSTA TI basewide health and safety plan (PRC 1998). The sampling approach and laboratory analytical protocols for the groundwater well installation activities are summarized below.

4.1 SAMPLING LOCATIONS

Five monitoring wells will be installed in areas where it has been determined that additional water quality data should be collected. Four groundwater monitoring wells will be installed downgradient of Debris Disposal Areas A and B. One of the four wells will be installed to replace missing well 12-MW10, formerly located near the southwestern edge of the excavation near Building 1133 (see Figure 1). It is believed that this well was inadvertently damaged during recent soil excavation activities in September 1999. A fifth monitoring well will be installed near Building 1108 at a location that is downgradient from the PCB removal near Halyburton Court.

4.2 SAMPLE COLLECTION AND HANDLING

Monitoring wells will be drilled using a truck-mounted, hollow-stem auger drill rig with approximately 8-inch-outer-diameter auger flights. A geologist will prepare a lithologic log of each monitoring well, using the Unified Soil Classification System and the Munsell color chart. Groundwater samples will be stored in an iced-cooler and transported to a California-certified, Navy-approved laboratory for analysis.

4.2.1 Well Construction

Wells will be constructed following TtEMI's Well Installation SOP (see Appendix A). Boreholes for monitoring wells will be drilled to about 15 feet bgs. Monitoring wells will be constructed with artificial filter packs. The use of artificial filter packs allows for the well screen opening (slot size) to be larger than if the intake were placed in the formation material. This allows for faster collection of sediment-free groundwater samples. Factors considered in the filter pack design include filter pack grain size, screen slot size, length of screen interval, filter pack thickness, filter pack length, and filter material type.

Monitoring wells will be constructed through the hollow-stem auger using 2-inch-diameter, flush-joint-threaded Schedule 40 polyvinyl chloride (PVC) casings and 10-foot-long, 0.010-inch slotted (10 slots) PVC well screens. If possible, the wells will be screened such that 2 to 5 feet of screen interval are above the water table surface. This allows the top of the screen interval to remain above the water table surface during tidal fluctuations and allows the detection of floating, immiscible liquid phases. However, because of the shallow water table on TI, this may not be possible in all of the locations. The filter pack will fill the space around the casing from the base of the well to approximately 2 feet above the top of the slotted interval. A 1-foot-thick bentonite seal will be placed above the filter pack to prevent cement grout from entering the filter pack. Above the bentonite seal, the borehole will be filled with cement grout to the surface. Wells will be completed with a flush-mounted, traffic-rated well box. A locking well cap will be placed in the PVC casing for security. In areas with shallow water tables, the length of screen above the water table, the thickness of sand above the screen, and the thickness of the bentonite seal will be modified but will still conform to acceptable well construction practices.

4.2.2 Well Development

Wells will be developed following the procedures outlined in TtEMI's Monitoring Well Development SOP (see Appendix B). Monitoring wells will be developed no sooner than 24 hours after the well is completed to allow the cement grout to harden. Before monitoring wells are developed, water level measurements will be taken. Newly installed monitoring wells will be developed by a truck-mounted well surging rig, hand bailing and surging, or overpumping during the development process. Between 6 and 10 well casing volumes of groundwater will be purged from each monitoring well to remove sediments left in the well during well construction and to enhance hydraulic communication with the surrounding water-yielding sediments. Observations concerning the quantity and clarity of the water withdrawn will be recorded during this process. Temperature, pH, and specific conductivity also will be measured and recorded on water quality sheets.

4.2.3 Groundwater Sampling

The following groundwater sampling techniques are designed to ensure that data are of high quality and representative of field conditions and that sample contamination is minimized. The sampling procedure will follow TtEMI's Groundwater Sampling SOP (see Appendix C).

Before groundwater sampling begins, a round of groundwater levels will be taken in the new and existing monitoring wells in this area of the site. Groundwater-level measurements will be collected to provide information on hydraulic gradients at the site. Groundwater samples will be collected from the newly installed wells no sooner than 24 hours following well development. Samples will be collected after at least 3 well casing volumes have been purged and after temperature, conductivity, pH, and water clarity have stabilized. These parameters are considered to have stabilized when a set of three or more sequential measurements are within ±0.2 °C for temperature, ±3 percent for conductivity, and ±0.1 unit for pH (EPA 1996a). If the stabilization parameters do not fall within the specified ranges after 3 well volumes, the well will be purged until the parameters stabilize or until 4 well volumes have been purged. If during well purging, the well runs dry before the specified amount of purge water has been withdrawn, the well will be allowed to recharged. After the well has recharged, one set of parameters will be measured, and the well will be sampled. Temperature, conductivity, and pH will be measured using a Horiba water quality measuring unit. Groundwater samples will be collected with a Teflon® bailer and poured directly into laboratory-supplied containers. Measurements of temperature, conductivity, pH, and water clarity will be recorded in the field on water quality forms.

All samples will be given a sample identification label and will be documented on chain-of-custody forms, as described in the Draft QAPP for Installation Restoration Site 12 Additional Characterization (TtEMI 2000). All samples will be placed in a cooler with ice immediately after they are sealed. Ice will be placed in the coolers before daily sampling activities begin. At the completion of daily activities, the coolers will be sealed and shipped to the analytical laboratory.

4.2.4 Location of Missing Groundwater Monitoring Well

Groundwater monitoring Well 12-MW10 could not be located after soil excavation activities were completed near Building 1133. Using survey data for the missing well, surveyors pinpointed where the well should be found; however, the well was not located. TtEMI will continue to search for the missing well using manual digging, a small backhoe, or surface geophysical methodologies. After the well is found, TtEMI will properly abandon the well according to procedures consistent with local and state regulatory guidelines.

4.3 SAMPLE ANALYSES

Samples will be sent to a California-certified, Navy-approved laboratory for analysis. Table 2 summarizes laboratory detection limits for the specified methods. Detailed descriptions of off-site laboratory procedures and analytical methodologies, including quality control (QC) limits, are provided in the Draft QAPP for Installation Restoration Site 12 Additional Characterization (TtEMI 2000). All samples will be submitted to a local state-certified and Navy-approved laboratory and analyzed for the following parameters:

Analysis and Matrix	Method
VOCs in water	EPA Contract Laboratory Program (CLP) Low-level VOC
PCBs in water	EPA CLP PCBs
SVOCs in water	Low-level EPA CLP SVOC
Metals in water	Low-level EPA CLP Metals
TPH as purgeable and TPH as extractable (TPH-e) in water	EPA Method 8015B

All groundwater samples analyzed for TPH-e will receive a silica gel cleanup, as specified in EPA Method 3630C (with no solvent exchanges), to remove polar biogenic hydrocarbons.

The off-site laboratory is required to perform all methods and procedures in accordance with specified methods, its in-house quality assurance plan, and the Draft QAPP for Installation Restoration Site 12 Additional Characterization (TtEMI 2000). Table 2 summarizes laboratory detection limits for specified methods. Detailed descriptions of off-site laboratory procedures and analytical methodologies, including QC limits, are provided in the Draft QAPP for Installation Restoration Site 12 Additional Characterization (TtEMI 2000).

4.4 DECONTAMINATION PROCEDURES

Decontamination and cleaning procedures presented in the Draft QAPP for Installation Restoration Site 12 Additional Characterization (TtEMI 2000) will be followed to prevent contamination of the samples and cross-contamination between locations. Before each use, all sampling equipment will be decontaminated by steam cleaning or alternatively, by washing with a nonphosphate detergent such as Liquinox®. A double tap water rinse and single deionized water rinse will follow the steam cleaning or detergent wash.

4.5 SURVEYING

Following completion of the monitoring wells, a professional land surveyor, licensed by the State of California, will provide the elevation of each boring to an accuracy of 0.05 foot. The elevations will be surveyed relative to the 1929 U.S. Geological Survey Mean Lowest Low Water (MLLW) datum. To remain consistent with standard survey practices used at NAVSTA TI, a baseline of 100 feet will be added to the MLLW datum to remove the possibility of negative elevations. Horizontal locations of the monitoring wells will be surveyed using the State Plane Coordinate System. The survey data will be merged with existing survey data in the NAVSTA TI database.

4.6 INVESTIGATION-DERIVED WASTE

The handling and disposal of all investigation-derived waste (IDW) will be conducted in accordance with the RI/FS IDW management plan for NAVSTA TI (PRC 1992). IDW will be placed in Department of Transportation 17H 55-gallon drums, and the drums will be stored in a dedicated storage facility at TI until disposal. The drums will be labeled with contents, source, generation date, and point of contact. Before disposal, IDW will be characterized for known site contaminants. Based on the characterization results, IDW will be sent to appropriate landfills or treatment facilities for disposal. IDW will be disposed of within 90 days of generation, in accordance with state and federal regulations.

5.0 FIELD QUALITY ASSURANCE AND QUALITY CONTROL SAMPLES

Quality assurance/quality control (QA/QC) field sampling will follow the protocols detailed in this work plan and in the Draft QAPP for Installation Restoration Site 12 Additional Characterization (TtEMI 2000) dated January 7, 2000. QA/QC field samples will include blanks and duplicates to assess whether data quality has been affected by field activities or the laboratory. QA/QC field and laboratory samples to be collected for this project will consist of field duplicates, equipment rinsate blanks, and matrix spike/matrix spike duplicates (MS/MSD), as described below:

- Field Duplicates: Field duplicates are taken to obtain precision data on handling, shipping, storage, preparation, and analysis of groundwater samples. Duplicate groundwater samples will be collected at a frequency of 1 for every 10 samples.
- Equipment Rinsate Blanks: One equipment rinsate blank will be collected during groundwater sampling activities by passing organic-free reagent-grade water through one of the disposable bailers representative of the lot of bailers. Analyses to be completed on equipment rinsate blanks will be the same as for the analyses identified in Section 4.3.
- MS/MSD: The analytical laboratory is required to analyze MS/MSD samples at a frequency of 1 for every 20 groundwater samples submitted to help assess the accuracy and precision of the analysis. Three times the normal sample volume will be collected for samples intended for MS/MSD analysis. Samples selected for MS/MSD analysis will not be equipment rinsate blanks or trip blanks.

6.0 SAMPLE HANDLING AND DOCUMENTATION

The following section presents procedures for sample identification and labeling. Section B4 in the Draft QAPP for Installation Restoration Site 12 Additional Characterization (TtEMI 2000) describes sample handling procedures, sample containerization and preservation, and sample documentation. Documentation and records, including field forms and logbooks, are discussed in Section A4.4, and blank field forms are presented in Appendix 1 of the Draft QAPP for Installation Restoration Site 12 Additional Characterization (TtEMI 2000).

6.1 SAMPLE IDENTIFICATION AND LABELING

Each sample will receive a 10-digit identification number in the following format:

CTO Number	Site Number	Sample Type	Sample Number
314	12	WA	xxx

where	314	= CTO number
	12	= Site 12
	WA	= Water sample
	xxx	= Sequential number

Each sampling location will also be given a discrete field identification number as follows:

Site Number	Location Type	Location Number
12	MW	xxx

where	12	= Site 12
	MW	= Monitoring well
	xxx	= Sequential number

6.2 SAMPLE CONTAINERIZATION AND HOLDING TIME

Table B-1 in the Draft QAPP for Installation Restoration Site 12 Additional Characterization (TtEMI 2000) presents the required sample container, preservation, and holding time for each analytical method.

6.3 DOCUMENTATION

During field sampling, several forms of documentation are maintained, including bound field logbooks, boring logs, daily QC reports, and chain-of-custody forms. This documentation is necessary for database input of new samples of data and to provide an accurate record of sampling events and field observations. Documentation and records, including field forms and bound logbooks, are discussed in Section A4.4 of the Draft QAPP for Installation Restoration Site 12 Additional Characterization, and blank field forms are presented in Appendix 1 of the Draft QAPP for Installation Restoration Site 12 Additional Characterization (TtEMI 2000).

7.0 HEALTH AND SAFETY

Field work will be conducted in accordance with TtEMI's health and safety program (PRC 1995) and with the NAVSTA TI basewide health and safety plan (PRC 1998). The plan conforms to the requirements of (1) Title 29 of the Code of Federal Regulations 1910.120 (b) (4); (2) the U.S. Army Corps of Engineers Engineer Manual 385-1-1, Safety and Health Requirements (USACE 1996); and (3) Navy Health and Safety Plan Review Guidance (Navy 1996).

The planned investigation will involve intrusive tasks; as a result, care must be exercised to ensure personnel safety and to protect underground utilities from potential damage. Existing engineering plans, drawings, diagrams, and other information showing underground utilities will be used to position the proposed monitoring well locations. Underground Services Alert will also be notified after proposed boring locations have been marked in the field and at least 48 hours before drilling activities for utility clearances. Underground utilities, including electrical, sewer, and water lines and any other buried features that may affect drilling, will be identified by a TtEMI subcontractor before work commences.

An excavation permit for soil boring and well construction will be obtained through the San Francisco Department of Public Works (DPW). The excavation permit will allow the San Francisco DPW to evaluate other potential impacts, such as natural and historic resources and coordination with other contractors and tenants. Well installation permits will also be obtained through the City and County of San Francisco Department of Public Health Bureau of Environmental Health Management. Personal protective equipment upgrades and stop-work conditions are defined in the NAVSTA TI basewide health and safety plan (PRC 1998).

8.0 REPORTING AND SCHEDULE

Preliminary unvalidated data will be available 30 days after the completion of field work. After analytical results from the field investigation are received from the laboratory, the data will be validated in accordance with the procedures specified in the Draft QAPP for Installation Restoration Site 12 Additional Characterization (TtEMI 2000) and EPA guidance (EPA 1994). These analytical results will be examined and used to plan additional action. TtEMI will prepare a technical memorandum that summarizes the results of the groundwater sampling investigation. Laboratory data will be presented as an appendix to the technical memorandum. In addition, the data will be incorporated into the NAVSTA TI RI database for use in the RI/FS and the human health risk assessment.

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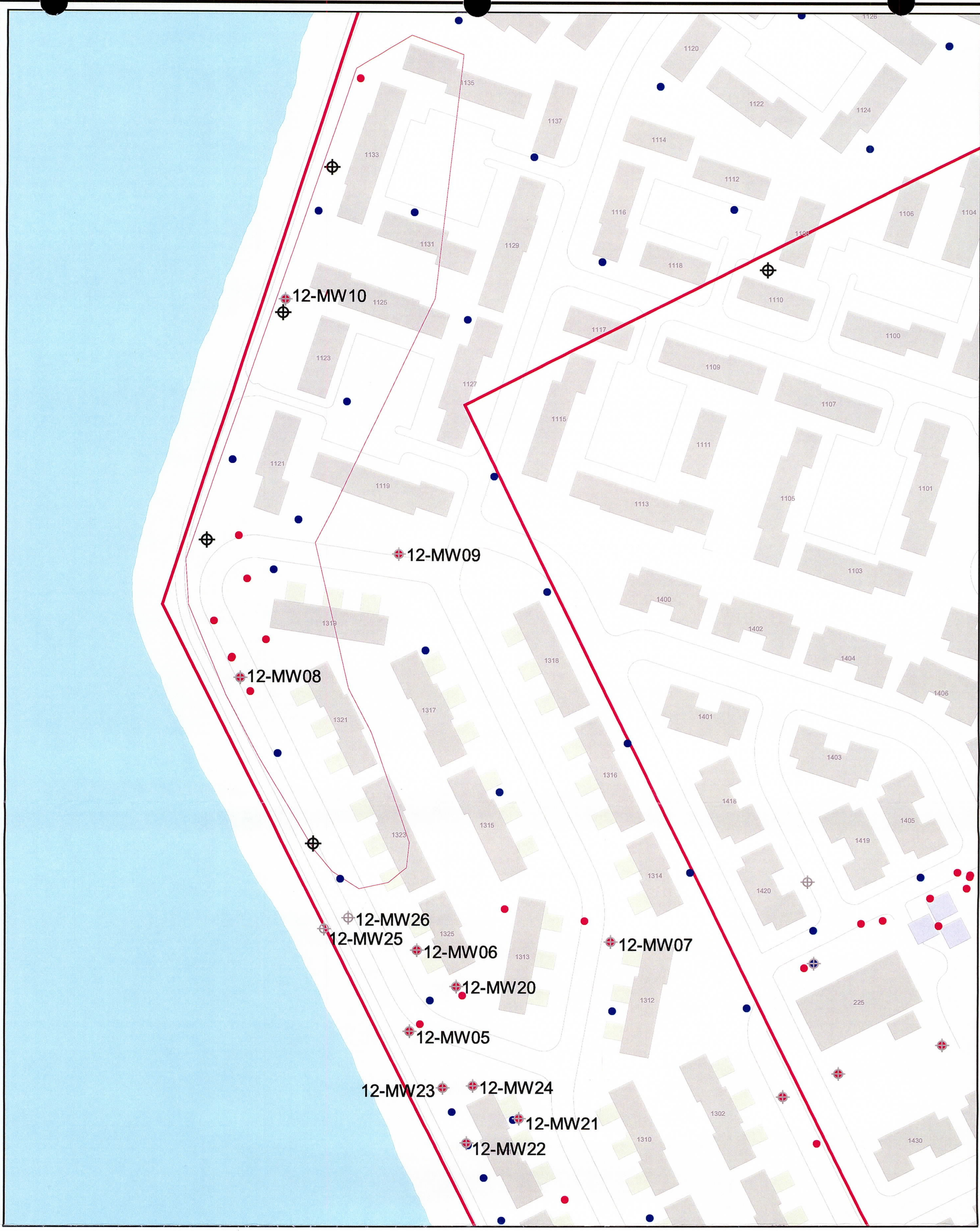
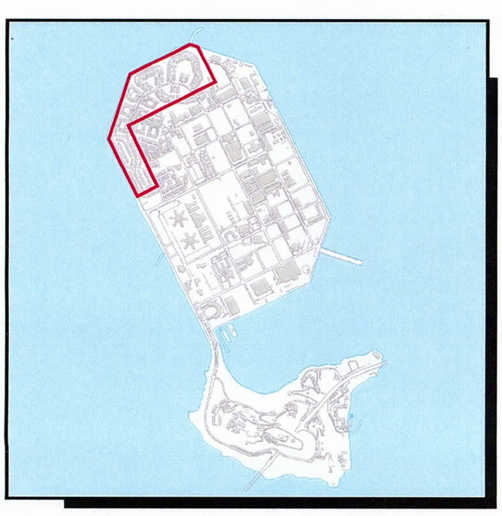
FIGURE





PROPOSED MONITORING WELL LOCATIONS
EXISTING MONITORING WELLS
VOCs DETECTED IN WATER
VOCs NOT DETECTED IN WATER
DEBRIS AREA
IR SITE
UNDERGROUND STORAGE TANKS
BUILDINGS
ROADS

N

25 0 25 50 Feet

Tetra Tech EM Inc.

SITE 12
TREASURE ISLAND, CALIFORNIA

FIGURE 1

PROPOSED MONITORING WELL LOCATIONS

01/09/01 v:\treasure island\projects\site12\teri'sfolder\additionalmw.apr TtEMI-SF Teri Pham

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TABLES

TABLE 1

DATA QUALITY OBJECTIVES SUMMARY
NAVAL STATION TREASURE ISLAND
(Page 1 of 1)

Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7
State the Problem	**Identify the Decision**	**Identify Inputs to the Decision**	**Define the Study Boundaries**	**Develop Decision Rules**	**Specify Acceptable Tolerable Limits on Decision Errors**	**Optimize the Sampling Design**
• Contaminants may be migrating in groundwater from Debris Disposal Areas A and B or Building 1133 towards San Francisco Bay at concentrations that pose a risk to ecological receptors.	• Are contaminants present in groundwater downgradient from Debris Disposal Areas A and B or Building 1133 at concentrations that pose a potential risk to ecological receptors?	• Site history • Existing chemical data • Validated, defensible analytical data for groundwater from proposed locations • Screening criteria for groundwater	• The horizontal boundary of the study area is the boundary of Site 12. • The vertical limit of the study area is 15 feet bgs.	• If any chemicals are detected in groundwater at concentrations exceeding applicable water quality criteria, then additional investigation or monitoring will be considered. If no chemicals are detected in groundwater at concentrations exceeding applicable water quality criteria, then no further investigation and limited groundwater monitoring will be conducted.	• False negative error will be minimized by adherence to selected sampling and analytical methods. • False positive error will be minimized by the proper application of selected sampling and analytical methods.	• Monitoring wells will be installed at four locations downgradient from debris disposal areas. • Groundwater samples will be collected at each of the four locations after the well has been developed. • All samples will be analyzed for PCBs, pesticides, TPH, SVOCs, and VOCs.

Notes:
PCB = Polychlorinated biphenyl
TPH = Total petroleum hydrocarbons
SVOC = Semivolatile organic compound
VOC = Volatile organic compound
bgs = Below ground surface

TABLE 2
CONTRACT-REQUIRED DETECTION LIMITS AND SCREENING CRITERIA

Compound	Contract Required Detection Limit (µg/L)	Laboratory Low Level Reporting Limit (µg/L)	Screening Criterion (µg/L)	CRDL Below Criterion?	LLLRL* Below Criterion?
METALS					
Aluminum	50.00	14.30	NE	NA	NA
Antimony	6.00	2.70	500	Yes	Yes
Arsenic	10.00	1.90	0.14	No	No
Barium	200.00	5.60	NE	NA	NA
Beryllium	4.00	0.20	0.0117	No	No
Cadmium	1.00	0.30	9.3	Yes	Yes
Calcium	5,000.00	124.00	NE	NA	NA
Chromium[1]	10.00	0.90	50.35	Yes	Yes
Cobalt	50.00	2.00	NE	NA	NA
Copper	4.00	1.70	3.7	No	Yes
Iron	100.00	25.40	NE	NA	NA
Lead	3.00	1.00	5.6	Yes	Yes
Magnesium	5,000.00	133.00	NE	NA	NA
Manganese	15.00	0.40	100	Yes	Yes
Mercury	0.20	0.10	0.025	No	No
Molybdenum	5.00	1.50	NE	NA	NA
Nickel	8.00	1.70	8.3	Yes	Yes
Potassium	5,000.00	261.00	NE	NA	NA
Selenium	5.00	2.40	71	Yes	Yes
Silver	2.00	1.90	0.92	No	No
Sodium	5,000.00	443.00	NE	NA	NA
Thallium	2.00	2.70	6.3	Yes	Yes
Tin	10.00	1.60	NE	NA	NA
Vanadium	50.00	1.50	NE	NA	NA
Zinc	20.00	1.60	85	Yes	Yes
POLYCHLORINATED BIPHENYLS					
Aroclor-1016	0.50	0.1	0.000045	No	No
Aroclor-1221	0.50	0.1	0.000045	No	No
Aroclor-1232	0.50	0.1	0.000045	No	No
Aroclor-1242	0.50	0.1	0.000045	No	No
Aroclor-1248	0.50	0.1	0.000045	No	No
Aroclor-1254	0.50	0.1	0.000045	No	No
Aroclor-1260	0.50	0.1	0.000045	No	No
SEMIVOLATILE ORGANIC COMPOUNDS					
1,2,4-Trichlorobenzene	10.00	2.50	129	Yes	Yes
1,2-Dichlorobenzene	5.00	1.25	129	Yes	Yes
1,3-Dichlorobenzene	5.00	1.25	129	Yes	Yes

TABLE 2
CONTRACT-REQUIRED DETECTION LIMITS AND SCREENING CRITERIA

Compound	Contract Required Detection Limit (µg/L)	Laboratory Low Level Reporting Limit (µg/L)	Screening Criterion (µg/L)	CRDL Below Criterion?	LLLRL* Below Criterion?
1,4-Dichlorobenzene	5.00	1.25	129	Yes	Yes
2,2'-Oxybis(1-Chloropropane)	10.00	2.50	NE	NA	NA
2,4,5-Trichlorophenol	25.00	6.25	11	No	Yes
2,4,6-Trichlorophenol	10.00	2.50	6.5	No	Yes
2,4-Dichlorophenol	10.00	2.50	790	Yes	Yes
2,4-Dimethylphenol	10.00	2.50	110	Yes	Yes
2,4-Dinitrophenol	25.00	6.25	NE	NA	NA
2,4-Dinitrotoluene	10.00	2.50	9.1	No	Yes
2,6-Dinitrotoluene	10.00	2.50	118	Yes	Yes
2-Chloronaphthalene	10.00	2.50	4300	Yes	Yes
2-Chlorophenol	10.00	2.50	400	Yes	Yes
2-Methylnaphthalene	10.00	2.50	60	Yes	Yes
2-Methylphenol	10.00	2.50	NE	NA	NA
2-Nitroaniline	25.00	6.25	NE	NA	NA
2-Nitrophenol	10.00	2.50	970	Yes	Yes
3,3'-Dichlorobenzidine	10.00	2.50	0.077	No	No
3-Nitroaniline	25.00	6.25	NE	NA	NA
4,6-Dinitro-2-Methylphenol	25.00	6.25	765	Yes	Yes
4-Bromophenyl-Phenylether	10.00	2.50	NE	NA	NA
4-Chloro-3-Methylphenol	10.00	2.50	NE	NA	NA
4-Chloroaniline	10.00	2.50	NE	NA	NA
4-Chlorophenyl-Phenylether	10.00	2.50	NE	NA	NA
4-Methylphenol	10.00	2.50	NE	NA	NA
4-Nitroaniline	25.00	6.25	970	Yes	Yes
4-Nitrophenol	25.00	6.25	970	Yes	Yes
Acenaphthene	10.00	2.50	710	Yes	Yes
Acenaphthylene	10.00	2.50	60	Yes	Yes
Anthracene	10.00	2.50	110000	Yes	Yes
Benzo(a)Anthracene	10.00	2.50	0.031	No	No
Benzo(a)Pyrene	10.00	2.50	0.031	No	No
Benzo(b)Fluoranthene	10.00	2.50	0.031	No	No
Benzo(g,h,i)Perylene	10.00	2.50	60	Yes	Yes
Benzo(k)Fluoranthene	10.00	2.50	0.031	No	No
Bis(2-Chloroethoxy)Methane	10.00	2.50	NE	NA	NA
Bis(2-Chloroethyl)Ether	10.00	2.50	1.4	No	No
Bis(2-Chloroisopropyl)Ether	10.00	2.50	5.9	No	Yes
Bis(2-Ethylhexyl)Phthalate	4.00	1.00	NE	NA	NA
Butylbenzylphthalate	10.00	2.50	5200	Yes	Yes

TABLE 2
CONTRACT-REQUIRED DETECTION LIMITS AND SCREENING CRITERIA

Compound	Contract Required Detection Limit (µg/L)	Laboratory Low Level Reporting Limit (µg/L)	Screening Criterion (µg/L)	CRDL Below Criterion?	LLLRL* Below Criterion?
Carbazole	10.00	2.50	NE	NA	NA
Chrysene	10.00	2.50	0.031	No	No
Di-N-Butylphthalate	10.00	2.50	12000	Yes	Yes
Di-N-Octylphthalate	10.00	2.50	12000	Yes	Yes
Dibenz(a,h)Anthracene	10.00	2.50	0.031	No	No
Dibenzofuran	10.00	2.50	6400	Yes	Yes
Diethylphthalate	10.00	2.50	2944	Yes	Yes
Dimethylphthalate	10.00	2.50	2900000	Yes	Yes
Fluoranthene	10.00	2.50	16	Yes	Yes
Fluorene	10.00	2.50	14000	Yes	Yes
Hexachlorobenzene	10.00	2.50	0.00077	No	No
Hexachlorobutadiene	10.00	2.50	50	Yes	Yes
Hexachlorocyclopentadiene	10.00	2.50	17000	Yes	Yes
Hexachloroethane	10.00	2.50	8.9	No	Yes
Indeno(1,2,3-cd)Pyrene	10.00	2.50	0.031	No	No
Isophorone	10.00	2.50	600	Yes	Yes
N-Nitroso-Di-N-Propylamine	10.00	2.50	1.4	No	No
N-Nitrosodiphenylamine (1)	10.00	2.50	16	Yes	Yes
Naphthalene	10.00	2.50	470	Yes	Yes
Nitrobenzene	10.00	2.50	1900	Yes	Yes
Pentachlorophenol	25.00	6.25	7.9	No	Yes
Phenanthrene	10.00	2.50	4.6	No	Yes
Phenol	10.00	2.50	4600000	Yes	Yes
Pyrene	10.00	2.50	11000	Yes	Yes
TOTAL PETROLEUM HYDROCARBONS					
TPH - Extractable[2] (diesel range)	100.00	NA	NE	NA	NA
TPH - Extractable[2] (motor oil range)	100.00	NA	NE	NA	NA
TPH - Purgeable (gasoline range)	50.00	NA	NE	NA	NA
VOLATILE ORGANIC COMPOUNDS					
1,1,1-Trichloroethane	2.00	2.00	6,240	Yes	Yes
1,1,2,2-Tetrachloroethane	2.00	2.00	11	Yes	Yes
1,1,2-Trichloroethane	2.00	2.00	42	Yes	Yes
1,1-Dichloroethane	2.00	2.00	NE	NA	NA
1,1-Dichloroethene	2.00	2.00	3.2	Yes	Yes
1,2-Dichloroethane	0.50	0.50	99	Yes	Yes
1,2-Dichloroethene, Total	2.00	2.00	NE	NA	NA
cis-1,2-Dichloroethene	2.00	2.00	44,800	Yes	Yes
trans-1,2-Dichloroethene	2.00	2.00	140,000	Yes	Yes

TABLE 2
CONTRACT-REQUIRED DETECTION LIMITS AND SCREENING CRITERIA

Compound	Contract Required Detection Limit (µg/L)	Laboratory Low Level Reporting Limit (µg/L)	Screening Criterion (µg/L)	CRDL Below Criterion?	LLLRL* Below Criterion?
1,2-Dichloropropane	2.00	2.00	39	Yes	Yes
2-Butanone	2.00	2.00	NE	NA	NA
2-Hexanone	2.00	2.00	NE	NA	NA
4-Methyl-2-Pentanone	2.00	2.00	NE	NA	NA
Acetone	2.00	2.00	NE	NA	NA
Benzene	0.50	0.50	71	Yes	Yes
Bromodichloromethane	2.00	2.00	22	Yes	Yes
Bromoform	2.00	2.00	360	Yes	Yes
Bromomethane	1.00	1.00	4,000	Yes	Yes
Carbon Disulfide	2.00	2.00	NE	NA	NA
Carbon Tetrachloride	0.50	0.50	4.4	Yes	Yes
Chlorobenzene	2.00	2.00	129	Yes	Yes
Chloroethane	2.00	2.00	NE	NA	NA
Chloroform	2.00	2.00	470	Yes	Yes
Chloromethane	2.00	2.00	6,400	Yes	Yes
cis-1,3-Dichloropropene	0.50	0.50	1700	Yes	Yes
Dibromochloromethane	2.00	2.00	34	Yes	Yes
Ethylbenzene	2.00	2.00	430	Yes	Yes
Methylene Chloride	2.00	2.00	29,000	Yes	Yes
Styrene	2.00	2.00	NE	NA	NA
Tetrachloroethene	2.00	2.00	8.85	Yes	Yes
Toluene	2.00	2.00	5,000	Yes	Yes
trans-1,3-Dichloropropene	0.50	0.50	NE	NA	NA
Trichloroethene	2.00	2.00	81	Yes	Yes
Vinyl Acetate	2.00	2.00	NE	NA	NA
Vinyl Chloride	0.50	0.50	525	Yes	Yes
Xylene (Total)	2.00	2.00	NE	NA	NA

Notes:
1 - Criterion applies to Cr^{+6}; detections of total Cr will be used for screening purposes.
2 - EPA method 8015B with silica gel cleanup.

CRDL -- Contract required detection limit.
LLLRL -- Laboratory low level reporting limit.
µg/L -- Micrograms per liter.
NA -- Not applicable.
NE -- No criterion established.
*LLLRL is the lowest practical reporting limit achievable using standard analytical methods.

APPENDICES

APPENDIX A

SOP 020: WELL INSTALLATION

SOP APPROVAL FORM

TETRA TECH EM INC.

ENVIRONMENTAL STANDARD OPERATING PROCEDURE

MONITORING WELL INSTALLATION

SOP NO. 020

REVISION NO. 3

Last Reviewed: December 2000

RRiesing
Quality Assurance Approved

December 19, 2000
Date

DS.0314.15091

1.0 BACKGROUND

Groundwater monitoring wells are designed and installed for a variety of reasons including: (1) detecting the presence or absence of contaminants, (2) collecting groundwater samples representative of in situ aquifer chemical characteristics, or (3) measuring water levels for determining groundwater potentiometric head and groundwater flow direction.

Although detailed specifications for well installation may vary in response to site-specific conditions, some elements of well installation are common to most situations. This standard operating procedure (SOP) discusses common methods and minimum standards for monitoring well installation for Tetra Tech EM Inc. (Tetra Tech) projects. The SOP is based on widely recognized methods described by the U.S. Environmental Protection Agency (EPA) and American Society for Testing and Materials (ASTM). However, well type, well construction, and well installation methods will vary with drilling method, intended well use, subsurface characteristics, and other site-specific criteria. In addition, monitoring wells should be constructed and installed in a manner consistent with all local and state regulations. Detailed specifications for well installation should be identified within a site-specific work plan, sampling plan, or quality assurance project plan (QAPP).

General specifications and installation procedures for the following monitoring well components are included in this SOP:

- Monitoring well materials
  - Casing materials
  - Well screen materials
  - Filter pack materials
  - Annular sealant (bentonite pellets or chips)
  - Grouting materials
  - Tremie pipe
  - Surface completion and protective casing materials
  - Concrete surface pad and bumper posts
  - Uncontaminated water
- Monitoring well installation procedures
  - Well screen and riser placement
  - Filter pack placement
  - Temporary casing retrieval
  - Annular seal placement

  - Grouting
  - Surface completion and protective casing (aboveground and flush-mount)
  - Concrete surface pad and bumper posts
  - Permanent and multiple casing well installation

- Recordkeeping procedures

  - Surveying
  - Permits and well construction records
  - Monitoring well identification

Well installation methods will depend to some extent on the boring method. Specific boring or drilling protocols are detailed in other SOPs. The boring method, in turn, will depend on site-specific geology and hydrogeology and project requirements. Boring methods commonly used for well installation include:

- Hollow-stem augering
- Cable tool drilling
- Mud rotary drilling
- Air rotary drilling
- Rock coring

The hollow-stem auger method is preferred in areas where subsurface materials are unconsolidated or loosely consolidated and where the depth of the boring will be less than 100 feet. This maximum effective depth for hollow-stem augering depends on the diameter of the augers, the formation characteristics, and the strength and durability of the drilling equipment. This method is preferred because under the right conditions it is cost effective, addition of water into the subsurface is limited, continuous soil samples can easily be collected, and monitoring wells can easily be constructed within the hollow augers.

Cable tool drilling is a preferred method when the subsurface contains boulders, coarse gravels, or flowing sands, or when the operational depth of the hollow-stem auger is exceeded. However, this method is slow.

Rotary methods are generally used when other methods cannot be used. The use of drilling fluids or large amounts of water to maintain an open borehole, and the difficulty in obtaining representative samples limit the utility of rotary methods. However, rotary methods can be used to quickly and effectively drill deep wells through consolidated or unconsolidated materials. Modifications to this method such as dual-tube drilling procedures, drill-through casing hammers, or eccentric-type drill systems, can reduce the amount of fluids introduced into the well borehole.

Rock coring is an effective method when drilling in competent consolidated rock. Intact, continuous cores can be obtained, and limited amounts of fluid are required if the formations are not fractured.

1.1 PURPOSE

This SOP establishes the requirements and procedures for monitoring well installation. Monitoring wells should be designed to function properly throughout the duration of the monitoring program. The performance objectives for monitoring well installation are as follows:

- Ensure that the monitoring well will provide water samples representative of in situ aquifer conditions.
- Ensure that the monitoring well construction will last for duration of the project.
- Ensure that the monitoring well will not serve as a conduit for vertical migration of contaminants, particularly vertical migration between discrete aquifers.
- Ensure that the well diameter is adequate for all anticipated downhole monitoring and sampling equipment.

1.2 SCOPE

This SOP applies to the installation of monitoring wells. Although some of the procedures may apply to the installation of water supply wells, this SOP is not intended to cover the design and construction of such wells. The SOP identifies several well drilling methods related to monitoring well installation, but the scope of this SOP does not include drilling methods.

Other relevant SOPs include SOP 002 for decontamination of drilling and well installation equipment, SOP 005 for soil sampling, SOP 021 for monitoring well development, SOPs 010 and 015 for groundwater sampling from monitoring wells, and SOP 014 for measuring static water levels within monitoring wells.

1.3 DEFINITIONS

Annulus: The space between the monitoring well casing and the wall of the well boring.

Bentonite seal: A colloidal clay seal separating the sand pack from the annular grout seal.

Centralizer: A stainless-steel or plastic spacer that keeps the well screen and casing centered in the borehole.

Filter pack: A clean, uniform sand or gravel placed between the borehole wall and the well screen to prevent formation material from entering the screen.

Grout seal: A fluid mixture of (1) bentonite and water, (2) cement, bentonite, and water, or (3) cement and water placed above the bentonite seal between the casing and the borehole wall to secure the casing in place and keep water from entering the borehole.

Tremie pipe: A rigid pipe used to place the well filter pack, bentonite seal, or grout seal. The tremie pipe is lowered to the bottom of the well or area to be filled and pulled up ahead of the material being placed.

Well casing: A solid piece of pipe, typically polyvinyl chloride (PVC) or stainless steel, used to keep a well open in either unconsolidated material or unstable rock.

Well screen: A PVC or stainless steel pipe with openings of a uniform width, orientation, and spacing used to keep materials other than water from entering the well and to stabilize the surrounding formation.

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1.5 REQUIREMENTS AND RESOURCES

Well installation requires a completed boring with stable or supported walls. The type of drilling rig needed to complete the boring and the well construction materials required for monitoring well installation will depend on the drilling method used, the geologic formations present, and chemicals of concern in groundwater. The rig and support equipment used to drill the borehole is usually used to install the well. Under most conditions, the following items are also required for the proper installation of monitoring wells:

- Tremie pipe and funnel
- Bentonite pellets or chips
- Grouting supplies
- Casing materials
- Well screen materials
- Filter pack materials

- Surface completion materials (protective casing, lockable and watertight well cover, padlock)
- Electronic water level sounding device for water level measurement
- Measuring tape with weight for measuring the depth of the well and determining the placement of filter pack materials
- Decontamination equipment and supplies
- Site-specific work plan, field sampling plan, health and safety plan, and QAPP
- Monitoring Well Completion Record (see Figure 1)

2.0 MONITORING WELL INSTALLATION PROCEDURES

This section presents standard procedures for monitoring well installation and is divided into three subsections. Section 2.1 addresses monitoring well construction materials, while Section 2.2 describes typical monitoring well installation procedures. Section 2.3 addresses recordkeeping requirements associated with monitoring well installation. Monitoring well installation procedures described in work plans, sampling plans, and QAPPs should be fully consistent with the procedures outlined in this SOP as well as any applicable local and state regulations and guidelines.

2.1 MONITORING WELL CONSTRUCTION MATERIALS

Monitoring well construction materials should be specified in the site-specific work plan as well as in the statement of work for any subcontractors assisting in the well installation. Well construction materials that come in contact with groundwater should not measurably alter the chemical quality of groundwater samples with regard to the constituents being examined. The riser, well screen, and filter pack and annular sealant placement equipment should be steam cleaned or high-pressure water cleaned immediately prior to well installation. Alternatively, these materials can be certified by the manufacturer as clean and delivered to the site in protective wrapping. Samples of the filter pack, annular seal, and mixed grout should be retained as a quality control measure until at least one round of groundwater sampling and analysis is completed.

This section discusses material specifications for the following well construction components: casing, well screen, filter pack, annular sealant (bentonite pellets or chips), grout, tremie pipes, surface completion components (protective casing, lockable and water tight cap, and padlock), concrete surface pad, and uncontaminated water. Figure 2 shows the construction details of a typical monitoring well.

2.1.1 Casing Materials

The material type and minimum wall thickness of the casing should be adequate to withstand the forces of installation. If the casing has not been certified as clean by the manufacturer or delivered to and maintained in clean condition at the site, the casing should be steam cleaned or high-pressure water cleaned with water from a source of known chemistry immediately prior to installation (see Tetra Tech SOP No. 002). The ends of each casing section should be either flush-threaded or beveled for welding.

Schedule 40 or Schedule 80 PVC casing is typically used for monitoring well installation. Either type of casing is appropriate for monitoring wells with depths less than 100 feet below ground surface (bgs). If the well is deeper than 100 feet bgs, Schedule 80 PVC should be used.

Stainless steel used for well casing is typically Type 304 and is of 11-gauge thickness.

2.1.2 Well Screen Materials

Well screens should be new, machine-slotted or continuous wrapped wire-wound, and composed of materials most suited for the monitoring environment based on site characterization findings. Well screens are generally constructed of the same materials used for well casing (PVC or stainless steel). The screen should be plugged at the bottom with the same material as the well screen. Alternatively, a short (1- to 2-foot) section of casing material with a bottom (sump) should be attached below the screen. This assembly must be able to withstand installation and development stresses without becoming dislodged or damaged. The length of the slotted area should reflect the interval to be monitored.

If the well screen has not been certified as clean by the manufacturer or delivered to and maintained in clean condition at the site, the screen should be steam cleaned or high-pressure water cleaned with water from a source of known chemistry immediately prior to installation (see Tetra Tech SOP No. 002).

The minimum internal diameter of the well screen should be chosen based on the particular application. A minimum diameter of 2 inches is usually needed to allow for the introduction and withdrawal of sampling devices. Typical monitoring well screen diameters are 2 inches and 4 inches.

The slot size of the well screen should be determined relative to (1) the grain size of particles in the aquifer to be monitored and (2) the gradation of the filter pack material.

Screen length and monitoring well diameter will depend on site-specific considerations such as intended well use, contaminants of concern, and hydrogeology. Some specific considerations include the following:

- Water table wells should have screens of sufficient length and diameter to monitor the water table and provide sufficient sample volume under high and low water table conditions.
- Wells with low recharge should have screens of sufficient length and diameter so that adequate sample volume can be collected.
- Wells should be screened over sufficiently short intervals to allow for monitoring of discrete migration pathways.
- Where light nonaqueous-phase liquids (LNAPL) or contaminants in the upper portion of a hydraulic unit are being monitored, the screen should be set so that the upper portion of the water-bearing zone is below the top of the screen.
- Where dense nonaqueous-phase liquids (DNAPL) are being monitored, the screen should be set within the lower portion of the water-bearing zone, just above a relatively impermeable lithologic unit.
- The screened interval should not extend across an aquiclude or aquitard.
- If contamination is known to be concentrated within a portion of a saturated zone, the screen should be constructed in a manner that minimizes the potential for cross-contamination within the aquifer.
- If downhole geophysical surveys are to be conducted, the casing and screen must be of sufficient diameter and constructed of the appropriate material to allow for effective use of the geophysical survey tools.
- If aquifer tests are to be conducted in a monitoring well, the slot size must allow sufficient flux to produce the required drawdown and recovery. The diameter of the well must be sufficient to house the pump and monitoring equipment, and allow sufficient

water flux (in combination with the screen slot size) to produce the required drawdown or recovery.

2.1.3 Filter Pack Materials

The primary filter pack consists of a granular material of known chemistry and selected grain size and gradation. The filter pack is installed in the annulus between the well screen and the borehole wall. The grain size and gradation of the filter pack are selected to stabilize the hydrologic unit adjacent to the screen and to prevent formation material from entering the well during development. After development, a properly filtered monitoring well is relatively free of turbidity.

A secondary filter pack is a layer of material placed in the annulus directly above the primary filter pack and separates the filter pack from the annular sealant. The secondary filter pack should be uniformly graded fine sand, with 100 percent by weight passing through a No. 30 U.S. Standard sieve, and less than 2 percent by weight passing through a No. 200 U.S. Standard sieve.

2.1.4 Annular Sealant (Bentonite Pellets or Chips)

The materials used to seal the annulus may be prepared as a slurry or used as dry pellets, granules, or chips. Sealants should be compatible with ambient geologic, hydrogeologic, and climatic conditions and any man-induced conditions anticipated to occur during the life of the well.

Bentonite (sodium montmorillonite) is the most commonly used annular sealant and is furnished in sacks or buckets in powder, granular, pelletized, or chip form. Bentonite should be obtained from a commercial source and should be free of impurities that may adversely impact the water quality in the well. Pellets are compressed bentonite powder in roughly spherical or disk shapes. Chips are large, coarse, irregularly shaped units of bentonite. The diameter of the pellets or chips should be less than one-fifth the width of the annular space into which they will be placed in order to reduce the potential for bridging. Granules consist of coarse particles of unaltered bentonite, typically smaller than 0.2 inch in diameter. Bentonite slurry is prepared by mixing powdered or granular bentonite with water from a source of known chemistry.

2.1.5 Grouting Materials

The grout backfill that is placed above the bentonite annular seal is ordinarily liquid slurry consisting of either (1) a bentonite (powder, granules, or both) base and water, (2) a bentonite and Portland cement base and water, or (3) a Portland cement base and water. Often, bentonite-based grouts are used when flexibility is desired during the life of the well installation (for example, to accommodate freeze-thaw cycles). Cement- or bentonite-based grouts are often used when cracks in the surrounding geologic material must be filled or when adherence to rock units, or a rigid setting is desired.

Each type of grout mixture has slightly different characteristics that may be appropriate under various physical and chemical conditions. However, quick-setting cements containing additives are not recommended for use in monitoring well installation because additives may leach from the cement and influence the chemistry of water samples collected from the well.

2.1.6 Tremie Pipe

A tremie pipe is used to place the filter pack, annular sealant, and grouting materials into the borehole. The tremie pipe should be rigid, have a minimum internal diameter of 1.0 inch, and be made of PVC or steel. The length of the tremie pipe should be sufficient to extend to the full depth of the monitoring well.

2.1.7 Surface Completion and Protective Casing Materials

Protective casings that extend above the ground surface should be made of aluminum, steel, stainless steel, cast iron, or a structural plastic. The protective casing should have a lid with a locking device to prevent vandalism. Sufficient clearance, usually 6 inches, should be maintained between the top of the riser and the top of protective casing. A water-tight well cap should be placed on the top of the riser to seal the well from surface water infiltration in the event of a flood. A weep hole should be drilled in the casing a minimum of 6 inches above the ground surface to enable water to drain out of the annular space.

Flush-mounted monitoring wells (wells that do not extend above ground surface) require a water-tight protective cover of sufficient strength to withstand heavy traffic. The well riser should be fitted with a locking water-tight cap.

2.1.8 Concrete Surface Pad and Bumper Posts

A concrete surface pad should be installed around each well when the outer protective casing is installed. The surface pad should be formed around the well casing. Concrete should be placed into the formed pad and into the borehole (on top of the grout), typically to a depth of 1 to 3 feet bgs (depending on state, federal, and local regulations). The protective casing is then installed into the concrete. As a general guideline, if the well casing is 2 inches in diameter, the concrete pad should be 3 feet square and 4 inches thick. If the well casing is 4 inches in diameter, the pad should be 4 feet square and 6 inches thick. Round concrete pads are also acceptable.

The finished pad should be sloped so that drainage flows away from the protective casing and off the pad. The finished pad should extend at least 1 inch below grade. If the monitoring wells are located in high traffic areas, a minimum of three bumper posts should be installed around the pad to protect the well. Bumper posts, consisting of steel pipes 3 to 4 inches in diameter and at least 5 feet long, should be installed in a radial pattern around the protective casing, beyond the edges of the cement pad. The base of the bumper posts should be installed 2 feet bgs in a concrete footing; the top of the post should be capped or filled with concrete.

2.1.9 Uncontaminated Water

Water used in the drilling process, to prepare grout mixtures, and to decontaminate the well screen, riser, and annular sealant injection equipment, should be obtained from a source of known chemistry. The water should not contain constituents that could compromise the integrity of the monitoring well installation.

2.2 MONITORING WELL INSTALLATION PROCEDURES

This section describes the procedures used to install a single-cased monitoring well, with either temporary casing or hollow-stem augers to support the walls of the boring in unconsolidated formations. The procedures are described in the order in which they are conducted, and include: (1) placement of well screen and riser pipe, (2) placement of filter pack, (3) progressive retrieval of temporary casing, (4) placement of annular seal, (5) grouting, (6) surface completion and installation of protective casing, and (7) installation of concrete pad and bumper posts.

The additional steps necessary to install a well with permanent or multiple casing strings are described at the end of this section.

2.2.1 Well Screen and Riser Placement

After the total depth of the boring is confirmed and the well screen depth interval and the height of the aboveground completion are determined, the screen and riser is assembled from the bottom up as it is lowered down the hole. The following procedures should be followed:

1. Measure the total depth of the boring using a weighted tape.
2. Determine the length of screen and casing materials required to construct the well.
3. Assemble the well parts from the bottom up, starting with the well sump or cap, well screen, and then riser pipe. Progressively lower the assembled length of pipe.
4. The length of the assembled pipe should not extend above the top of the installation rig.

The well sump or cap, well screen, and riser should be certified clean by the manufacturer or should be decontaminated before assembly and installation. No grease, oil, or other contaminants should contact any portion of the assembly. Flush joints should be tightened, and welds should be water tight and of good quality. The riser should extend above grade and be capped temporarily to prevent entrance of foreign materials during the remaining well completion procedures.

When the well screen and riser assembly is lowered to the predetermined level, it may float and require a method to hold it in place. For borings drilled using cable tool or air rotary drilling methods, centralizers should be attached to the riser at intervals of between 20 and 40 feet.

2.2.2 Filter Pack Placement

The filter pack is placed after the well screen and riser assembly has been lowered into the borehole. The steps below should be followed:

1. Determine the volume of the annular space in the filter pack interval. The filter pack should extend from the bottom of the borehole to at least 2 feet above the top of the well screen.
2. Assemble the required material (sand pack and tremie pipe).
3. Lower a clean or decontaminated tremie pipe down the annulus to within 1 foot of the base of the hole.
4. Pour the sand down the tremie pipe using a funnel; pour only the quantity estimated to fill the first foot.
5. Check the depth of sand in the hole using a weighted tape.
6. Pull the drill casing up ahead of the sand to keep the sand from bridging.
7. Continue with this process (steps 4 through 6) until the filter pack is at the appropriate depth.

If bridging of the filter pack occurs, break out the bridge prior to adding additional filter pack material. For wells less than 30 feet deep installed inside hollow-stem augers, the sand may be poured in 1-foot lifts without a tremie pipe.

Sufficient measurements of the depth to the filter pack material and the depth of the bottom of the temporary casing should be made to ensure that the casing bottom is always above the filter pack. The filter pack should extend 2 feet above the well screen (or more if required by state or local regulations). However, the filter pack should not extend across separate hydrogeologic units. The final depth interval, volume, and type of filter pack should be recorded on the Monitoring Well Completion Record (Figure 1).

A secondary filter pack may be installed above the primary filter pack to prevent the intrusion of the bentonite grout seal into the primary filter pack. A measured volume of secondary filter material should be added to extend 1 to 2 feet above the primary filter pack. As with the primary filter pack, a secondary filter pack must not extend into an overlying hydrologic unit. An on-site geologist should evaluate the need for a secondary filter pack by considering the gradation of the primary filter pack, the hydraulic head difference between adjacent units, and the potential for grout intrusion into the primary filter pack.

The secondary filter material is poured into the annular space through tremie pipe as described above. Water from a source of known chemistry may be added to help place the filter pack into its proper location. The tremie pipe or a weighed line inserted through the tremie pipe can be used to measure the top of the secondary filter pack as work progresses. The amount and type of secondary filter pack used should be recorded on the Monitoring Well Completion Record (Figure 1).

2.2.3 Temporary Casing Retrieval

The temporary casing or hollow-stem auger should be withdrawn in increments. Care should be taken to minimize lifting the well screen and riser assembly during withdrawal of the temporary casing or auger. It may be necessary to place the top head of the rig on the riser to hold it down. To limit borehole collapse in formations consisting of unconsolidated materials, the temporary casing or hollow-stem auger is usually withdrawn until the lowest point of the casing or auger is at least 2 feet, but no more than 5 feet, above the filter pack. When the geologic formation consists of consolidated materials, the lowest point of the casing or auger should be at least 5 feet, but no more than 10 feet, above the filter pack. In highly unstable formations, withdrawal intervals may be much less. After each increment, the depth to the primary filter pack should be measured to check that the borehole has not collapsed or that bridging has not occurred.

2.2.4 Annular Seal Placement

A bentonite pellet, chip, or slurry seal should be placed between the borehole and the riser on top of the primary or secondary filter pack. This seal retards the movement of grout into the filter pack. The thickness of the bentonite seal will depend on state and local regulations, but the seal should generally be between 3 and 5 feet thick.

The bentonite seal should be installed using a tremie pipe, lowered to the top of the filter pack and slowly raised as the bentonite pellets or slurry fill the space. Care must be taken so that bentonite pellets or chips do not bridge in the augers or tremie pipe. The depth of the seal should be checked with a weighted tape or the tremie pipe.

If a bentonite pellet or chip seal is installed above the water level, water from a known source should be added to allow proper hydration of the bentonite. Sufficient time should be allowed for the bentonite seal to hydrate. The volume and thickness of the bentonite seal should be recorded on the Monitoring Well Completion Record (Figure 1).

2.2.5 Grouting

Grouting procedures vary with the type of well design. The volume of grout needed to backfill the remaining annular space should be calculated and recorded on the Monitoring Well Completion Record (Figure 1). The use of alternate grout materials, including grouts containing gravel, may be necessary to control zones of high grout loss. Bentonite grouts should not be used in arid regions because of their propensity to desiccate. Typical grout mixtures include the following:

- Bentonite grout: about 1 to 1.25 pounds of bentonite mixed with 1 gallon of water
- Cement-bentonite grout: about 5 pounds of bentonite and one 94-pound bag of cement mixed with 7 to 8 gallons of water
- Cement grout: one 94-pound bag of cement mixed with 6 to 7 gallons of water

The grout should be installed by gravity feed through a tremie pipe. The grout should be mixed in batches in accordance with the appropriate requirements and then pumped into the annular space until full-strength grout flows out at the ground surface without evidence of drill cuttings or fluid. The tremie pipe should then be removed to allow the grout to cure.

The riser should not be disturbed until the grout sets and cures for the amount of time necessary to prevent a break in the seal between the grout and riser. For bentonite grouts, curing times are typically around 24 hours; curing times for cement grouts are typically 48 to 72 hours. However, the curing time required will vary with grout content and climatic conditions. The curing time should be documented in the Monitoring Well Completion Record (Figure 1).

2.2.6 Surface Completion and Protective Casing

Aboveground completion of the monitoring well should begin once the grout has set (no sooner than 24 hours after the grout was placed). The protective casing is lowered over the riser and set into the cured grout. The protective casing should extend below the ground surface to a depth below the frost line (typically 3 to 5 feet, depending on local conditions). The protective casing is then cemented in place. A minimum of 6 inches of clearance should be maintained between the top of the riser and the protective casing. A 0.5-inch diameter drainage or weep hole should be drilled in the protective casing approximately 6 inches above the ground surface to enable water to drain out of the annular space between the casing and riser. A water-tight cap should be placed on top of the riser to seal the well from surface water infiltration in the event of a flood. A lock should be placed on the protective casing to prevent vandalism.

For flush-mounted monitoring wells, the well cover should be raised above grade and the surrounding concrete pad sloped so that water drains away from the cover. The flush-mount completion should be installed in accordance with applicable state and local regulations.

2.2.7 Concrete Surface Pad and Bumper Posts

The concrete pad installed around the monitoring well should be sloped so that the drainage will flow away from the protective casing and off the pad. The finished pad should extend at least 1 inch below grade. If the monitoring wells are located in high traffic areas, a minimum of three bumper posts should be installed in a radial pattern around the protective casing, outside the cement pad. Specifications for concrete surface pads and bumper posts are described in Section 2.1.8.

2.2.8 Permanent and Multiple Casing Well Installation

When wells are installed through multiple saturated zones, special well construction methods should be used to assure well integrity and limit the potential for cross-contamination between geologic zones. Generally, these types of wells are necessary if relatively impermeable layers separate hydraulic units. Two procedures that may be used are described below.

In the first procedure, the borehole is advanced to the base of the first saturated zone. Casing is then anchored in the underlying impermeable layer (aquitard) by advancing the casing at least 1 foot into the aquitard and grouting to the surface. After the grout has cured, a smaller diameter borehole is drilled through the grout. This procedure is repeated until the zone of interest is reached. After the zone is reached, a conventional well screen and riser are set. A typical well constructed in this manner is shown on Figure 3.

A second acceptable procedure involves driving a casing through several saturated layers while drilling ahead of the casing. However, this method is not acceptable when the driven casing may structurally damage a competent aquitard or aquiclude and result in cross-contamination of the two saturated layers. This method should also be avoided when highly contaminated groundwater or nonaqueous-phase contamination may be dragged down into underlying uncontaminated hydrologic units.

2.3 RECORDKEEPING PROCEDURES

Recordkeeping procedures associated with monitoring well installation are described in the following sections. These include procedures for surveying, obtaining permits, completing well construction records, and identifying monitoring wells.

2.3.1 Surveying

Latitude, longitude, and elevation at the top of the riser should be determined for each monitoring well. A permanent notch or black mark should be made on the north side of the riser. The top of the riser and ground surface should be surveyed.

2.3.2 Permits and Well Construction Records

Local and state regulations should be reviewed prior to monitoring well installation, and any required well permits should be in-hand before the driller is scheduled.

Monitoring well installation activities should be documented in both the field logbook and on the Monitoring Well Completion Record (Figure 1). Geologic logs should be completed and, if necessary, filed with the appropriate regulatory agency within the appropriate time frame.

2.3.3 Monitoring Well Identification

Each monitoring well should have an individual well identification number or name. The well identification may be stamped in the metal surface upon completion or permanently marked by using another method. Current state and local regulations should be checked for identification requirements (such as township, range, section, or other identifiers in the well name).

FIGURE 1

MONITORING WELL COMPLETION RECORD

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MONITORING WELL COMPLETION RECORD

MONITORING WELL

MONITORING WELL NO.: ________
PROJECT: ________
SITE: ________
BOREHOLE NO.: ________
WELL PERMIT NO.: ________
TOC TO BOTTOM OF WELL: ________

DRILLING INFORMATION

DRILLING BEGAN:
DATE: ________ TIME: ________
WELL INSTALLATION BEGAN:
DATE: ________ TIME: ________
WELL INSTALLATION FINISHED:
DATE: ________ TIME: ________
DRILLING CO.: ________
DRILLER: ________
LICENSE: ________
DRILL RIG: ________
DRILLING METHOD:
☐ HOLLOW-STEM AUGER
☐ AIR ROTARY
☐ OTHER: ________
DIAMETER OF AUGERS:
ID: ________ OD: ________

WELL CASING

☐ SCHEDULE 40 PVC
☐ OTHER: ________
PRODUCT: ________
MFG. BY: ________
CASING DIAMETER:
ID: ________ OD: ________
LENGTH OF CASING: ________

WELL SCREEN

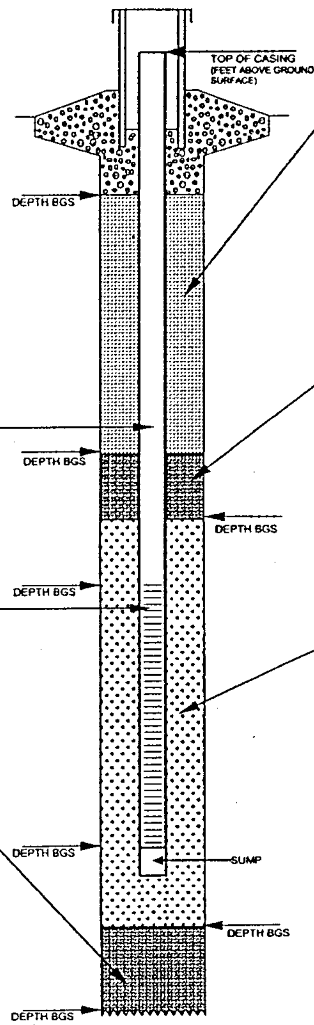
☐ SCHEDULE 40 PVC
☐ OTHER: ________
PRODUCT: ________
MFG. BY: ________
CASING DIAMETER:
ID: ________ OD: ________
SLOT SIZE: ________
LENGTH OF SCREEN: ________

BOREHOLE BACKFILL

AMOUNT CALCULATED: ________
AMOUNT USED: ________
☐ BENTONITE CHIPS, SIZE: ________
☐ BENTONITE PELLETS, SIZE: ________
☐ SLURRY: ________
☐ FORMATION COLLAPSE: ________
☐ OTHER: ________
PRODUCT: ________
MFG. BY: ________
METHOD INSTALLED:
☐ POURED ☐ TREMIE
☐ OTHER: ________

SURFACE COMPLETION

☐ FLUSH MOUNT
☐ ABOVE GROUND WITH BUMPER POST
☐ CONCRETE ☐ ASPHALT



SURVEY INFORMATION

TOC ELEVATION: ________
GROUND SURFACE ELEVATION: ________
NORTHING: ________
EASTING: ________
DATE SURVEYED: ________
SURVEY CO.: ________

ANNULAR SEAL

VOLUME CALCULATED: ________
AMOUNT USED: ________
☐ GROUT FORMULA (PERCENTAGES)
PORTLAND CEMENT: ________
BENTONITE: ________
WATER: ________
☐ PREPARED MIX
PRODUCT: ________
MFG. BY: ________
METHOD INSTALLED:
☐ POURED ☐ TREMIE
☐ OTHER: ________

BENTONITE SEAL

VOLUME CALCULATED: ________
AMOUNT USED: ________
☐ PELLETS, SIZE: ________
☐ CHIPS, SIZE: ________
☐ OTHER: ________
PRODUCT: ________
MFG. BY: ________
METHOD INSTALLED:
☐ POURED ☐ TREMIE
☐ OTHER: ________
AMOUNT OF WATER USED: ________

FILTER PACK

☐ PREPACKED FILTER
VOLUME CALCULATED: ________
AMOUNT USED: ________
☐ SAND, SIZE: ________
PRODUCT: ________
MFG. BY: ________
METHOD INSTALLED:
☐ POURED ☐ TREMIE
☐ OTHER: ________
WATER LEVEL: ________
(BTOC AFTER WELL INSTALLATION)

CENTRALIZERS USED?

☐ YES ☐ NO:
CENTRALIZER DEPTHS: ________ ________

LEGEND

BGS = BELOW GROUND SURFACE
BTOC = BELOW TOP OF CASING
N/A = NOT APPLICABLE
NR = NOT RECORDED
TOC = TOP OF CASING
ID = INSIDE DIAMETER
OD = OUTSIDE DIAMETER

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FIGURE 2

MONITORING WELL CONSTRUCTION DIAGRAM

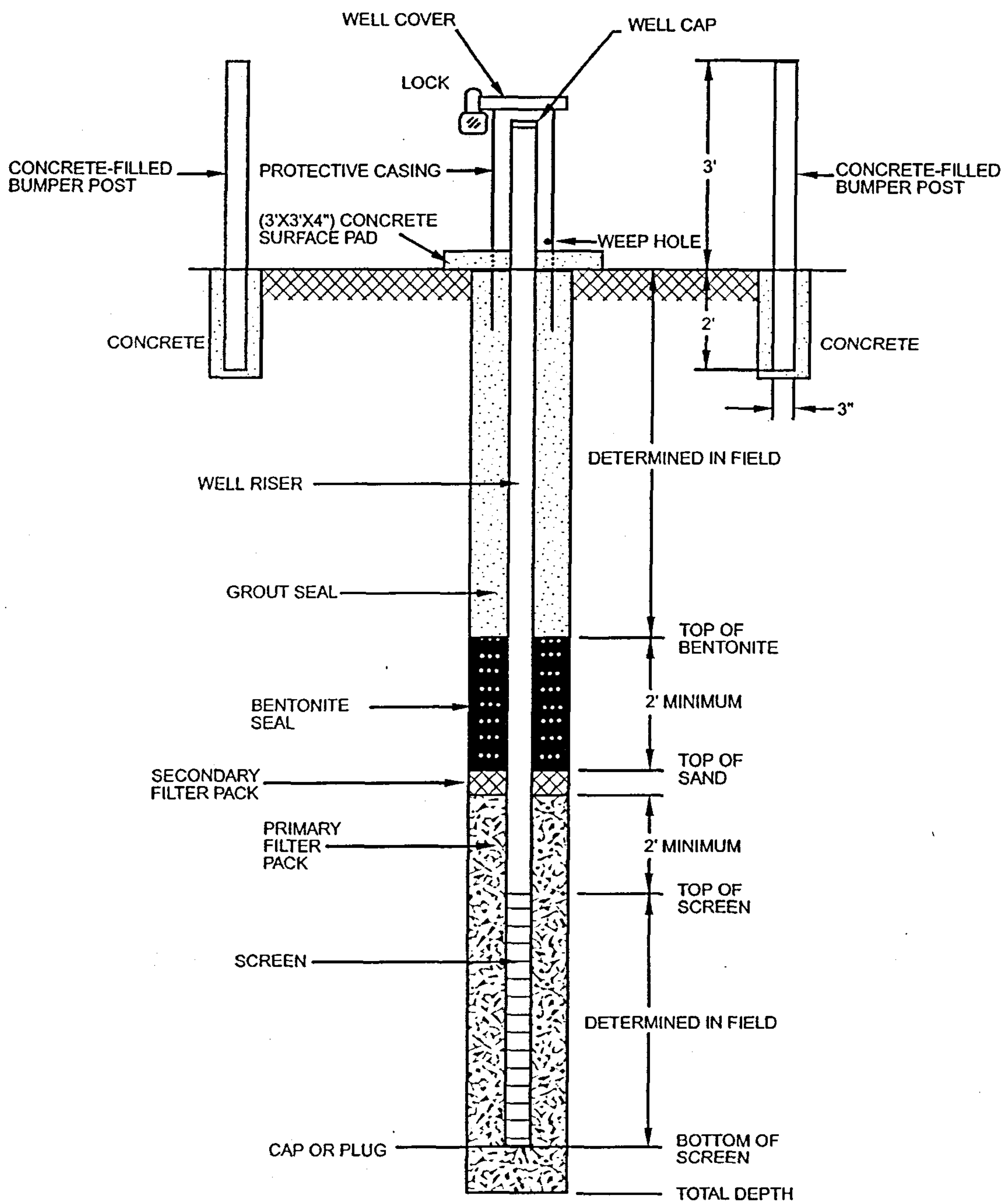

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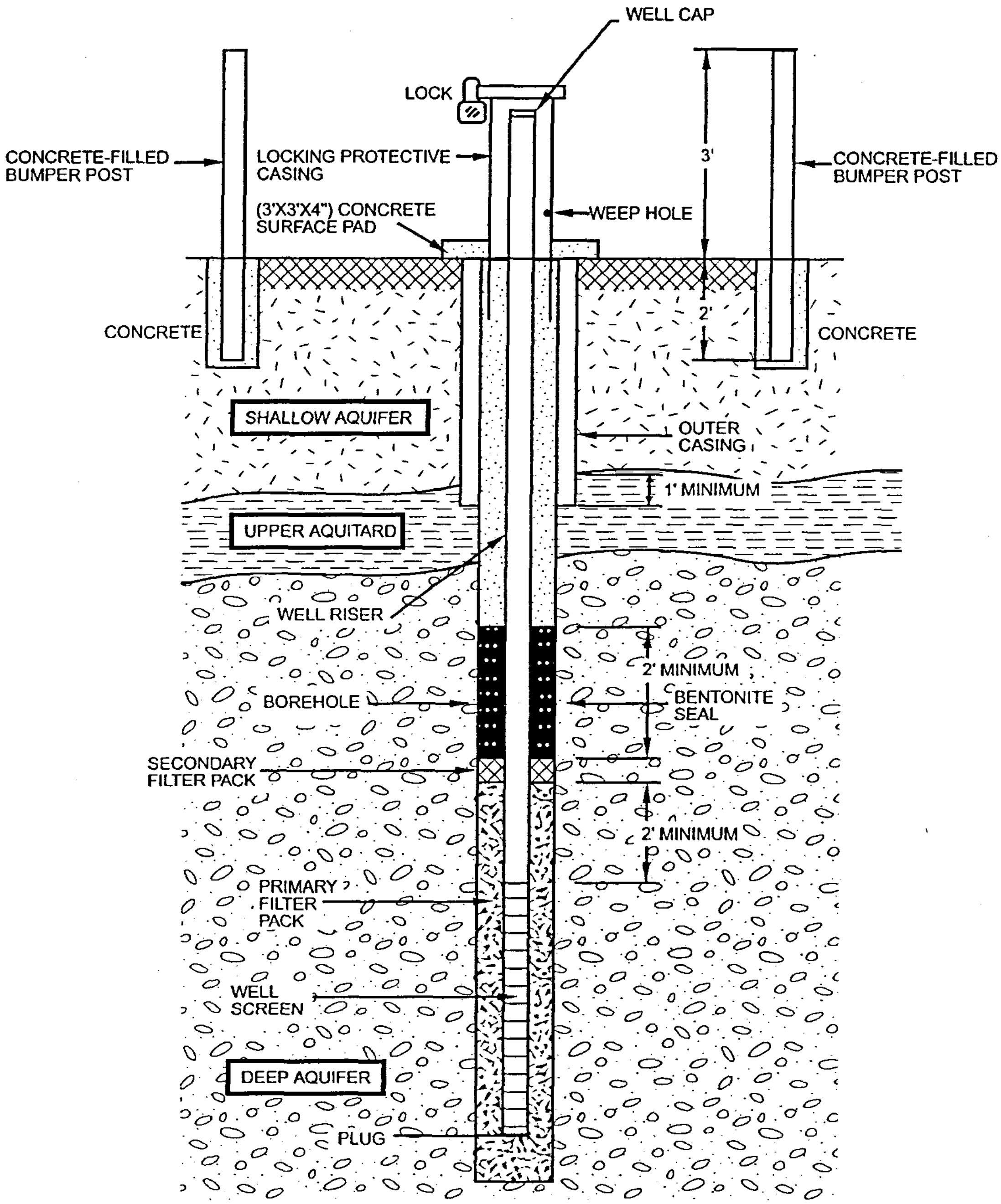
FIGURE 3

MULTIPLE CASING WELL CONSTRUCTION DIAGRAM



APPENDIX B

SOP 021: MONITORING WELL DEVELOPMENT

SOP APPROVAL FORM

TETRA TECH EM INC.

ENVIRONMENTAL STANDARD OPERATING PROCEDURE

Monitoring Well Development

SOP NO. 021

REVISION NO. 3

Last Reviewed: October 2000

KRiesing

Quality Assurance Approved

October 5, 2000

Date

DS.0314.15091

1.0 BACKGROUND

All drilling methods impair the ability of an aquifer to transmit water to a drilled hole. This impairment is typically a result of disturbance of soil grains (smearing) or the invasion of drilling fluids or solids into the aquifer during the drilling process. The impact to the hydrologic unit surrounding the borehole must be remediated so that the well hydraulics and samples collected from the monitoring well are representative of the aquifer.

Well development should be conducted as an integral step of monitoring well installation to remove the finer-grained material, typically clay and silt, from the geologic formation near the well screen and filter pack. (Monitoring well installation is discussed in standard operating procedure [SOP] No. 020.) The fine-grained particles may interfere with water quality analyses and alter the hydraulic characteristics of the filter pack and the hydraulic unit adjacent to the well screen. Well development improves the hydraulic connection between water in the well and water in the formation. The most common well development methods are surging, jetting, overpumping, and bailing.

The health and safety plan for the site should be followed to avoid exposure to chemicals of concern. Water, sediment, and other waste removed from a monitoring well should be disposed of in accordance with applicable federal, state, and local requirements.

1.1 PURPOSE

This SOP establishes the requirements and procedure for monitoring well development. Well development improves the hydraulic characteristics of the filter pack and borehole wall by performing the following functions:

- Reducing the compaction and the intermixing of grain sizes produced during drilling by removing fine material from the pore spaces.
- Removing the filter cake or drilling fluid film that coats the borehole as well as much or all of the drilling fluid and natural formation solids that have invaded the formation.
- Creating a graded zone of sediment around the screen, thereby stabilizing the formation so that the well can yield sediment-free water.

1.2 SCOPE

This SOP applies to the development of newly installed monitoring wells. The SOP identifies the most commonly used well development methods; these methods can be used individually or in combination to achieve the most effective well development. Selection of a particular method will depend on site conditions, equipment limitations, and other factors. The method selected and the rationale for selection should be documented in a field logbook or appropriate project reports.

1.3 DEFINITIONS

Aquifer: A geologic formation, group of formations, or part of a formation that is saturated and capable of storing and transmitting water.

Aquitard: a geologic formation, group of formations, or part of a formation through which virtually no water moves.

Bailer: A cylindrical sampling device with valves on either end, used to extract water from a well or borehole.

Bentonite seal: A colloidal (extremely fine particle that will not settle out of solution) clay seal separating the sand pack from the surface seal.

Drilling fluid: A fluid (liquid or gas) that may be used in drilling operations to remove cuttings from the borehole, to clean and cool the drill bit, and to maintain the integrity of the borehole during drilling.

Filter pack: A clean, uniform sand or gravel placed between the borehole wall and the well screen to prevent formation material from entering the screen.

Grout seal: A fluid mixture of (1) cement and water or (2) cement, bentonite, and water that is placed above the bentonite seal between the casing and the borehole wall to secure the casing in place and keep water from entering the borehole.

Hydraulic conductivity: A measure of the ease with which water moves through a geologic formation. Hydraulic conductivity, K, is typically measured in units of distance per time in the direction of groundwater flow.

Hydrologic units: Geologic strata that can be distinguished on the basis of capacity to yield and transmit fluids. Aquifers and confining units are types of hydrologic units.

Oil air filter: A filter or series of filters placed in the airflow line from an air compressor to reduce the oil content of the air.

Oil trap: A device used to remove oil from the compressed air discharged from an air compressor.

Riser: The pipe extending from the well screen to or above the ground surface.

Specific conductance: A measure of the ability of the water to conduct an electric current. Specific conductance is related to the total concentration of ionizable solids in the water and is inversely proportional to electrical resistance.

Static water level: The elevation of the top of a column of water in a monitoring well or piezometer that is not influenced by pumping or conditions related to well installation, hydrologic testing, or nearby pumpage.

Transmissivity: The volume of water transmitted per unit width of an aquifer over the entire thickness of the aquifer flow, under a unit hydraulic gradient.

Well screen: A cylindrical pipe with openings of a uniform width, orientation, and spacing used to keep materials other than water from entering the well and to stabilize the surrounding formation.

Well screen jetting (hydraulic jetting): A jetting method used for development; nozzles and a high pressure pump are used to force water outwardly through the screen, the filter pack, and sometimes into the adjacent geologic unit.

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1.5 REQUIREMENTS AND RESOURCES

The type of equipment used for well development will depend on the well development method. Well development methods and the equipment required are discussed in Section 2.1 of this SOP. In general, monitoring wells should be developed shortly after they are installed but no sooner than 24 hours after the placement of the grout seal, depending on the grout cure rate and well development method. Most drilling or well development rigs have pumps, air compressors, bailers, surge blocks, and other equipment that can be used to develop a monitoring well.

All downhole equipment should be properly decontaminated before and after each well is developed. See SOP No. 002 (General Equipment Decontamination) for details.

2.0 WELL DEVELOPMENT PROCEDURES

This section describes common well development methods, factors to be considered in selecting a well development method, procedures for initiating well development, well development duration, and calculations typically made during well development. In addition to this, procedures described in any work plans for well development should be fully consistent with local and state regulations and guidelines.

2.1 WELL DEVELOPMENT METHODS

Well development methods vary with the physical characterization of hydrologic units in which the monitoring well is screened and the drilling method used. The most common methods include mechanical surging, overpumping, air lift pumping, backwashing, surge bailing, and well jetting. These methods may be effective alone or may need to be combined (for example, overpumping combined with backwashing). Factors such as well design and hydrogeologic conditions will determine which well development method will be most practical and cost-effective. Commonly used well development methods are described in Sections 2.1.1 through 2.1.6.

The use of chemicals for monitoring well development should be avoided as much as possible. Introduction of chemicals may significantly alter groundwater chemistry in and around the well.

2.1.1 Mechanical Surging

The mechanical surging method forces water to flow in and out of the well screen by operating a plunger (or surge block) in the casing, similar to a piston in a cylinder. A typical surge block is shown in Figure 1. The surge block should fit snugly in the well casing to increase the surging action. The surge block is attached to a drill rod or drill stem and is of sufficient weight to cause the block to drop rapidly on the down stroke, forcing water contained in the borehole into the aquifer surrounding the well. In the recovery stroke or upstroke, water is lifted by the surge block, allowing water and fine sediments to flow back into the well from the aquifer. Down strokes and recovery strokes are usually 3 to 5 feet in length.

The surge block should be lowered into the water column above the well screen. The water column will effectively transmit the action of the block to the filter pack and hydrologic unit adjacent to the well screen. Development should begin above the screen and move progressively downward to prevent the surge block from becoming sand locked in the well. The initial surging action should be relatively gentle, allowing any material blocking the screen to break up, go into suspension, and then move into the well. As water begins to move easily both in and out of the screen, the surge block is usually lowered in increments to a level just above the screen. As the block is lowered, the force of the surging movement should be increased. In wells equipped with long screens, it may be more effective to operate the surge block in the screen to concentrate its actions at various levels.

A pump or bailer should be used periodically to remove dislodged sediment that may have accumulated at the bottom of the well during the surging process. The pump or bailer should be moved up and down at the bottom of the well to suspend and collect as much sediment as possible.

The accumulation of material developed from a specific screen interval can be measured by sounding the total depth of the well before and after surging. Continue surging until little or no sand accumulates.

2.1.2 Overpumping

Overpumping involves pumping the well at a rate substantially higher than it will be pumped during well purging and groundwater sampling. This method is most effective on coarse-grained formations and is usually conducted in conjunction with mechanical surging or backwashing. Overpumping is commonly implemented using a submersible pump. In cases were the water table is less than 30 feet from the top of the casing, it is possible to overpump the well with a centrifugal pump. The intake pipe is lowered into the water column at a depth sufficient to ensure that the water in the well is not drawn down to the pump intake level. The inflow of water at the well screen is not dependent on the location of the pump intake as long as it remains submerged.

Overpumping will induce a high velocity water flow, resulting in the flow of sand, silt, and clay into the well, opening clogged screen slots and cleaning formation voids and fractures. The movement of these particles at high flow rates should eliminate particle movement at the lower flow rates used during well purging and sampling. The bridging of particles against the screen because of the flow rate and direction created by overpumping may be overcome by using mechanical surging or backwashing in conjunction with this method.

2.1.3 Air Lift Pumping

Air lift pumping uses a two-pipe system consisting of an air injection pipe and a discharge pipe. In this well development method, an air lift pump is operated by cycling the air pressure on and off for short periods of time. This operation provides a surging action that can dislodge fine-grained particles in the vicinity of the well screen. Subsequently applying a steady low pressure removes the fines drawn into the well by the surging action.

The bottom of the air lift should be at least 10 feet above the top of the well screen. Air is injected through an inner pipe at sufficient pressure to bubble out directly into the surrounding discharge pipe. The bubbles formed by the injected air cause the column of water in the discharge pipe to be lifted upward and allow water from the aquifer to flow into the well. This arrangement prevents injected air from entering the well screen. Pumping air through the well screen and into the filter pack and adjacent hydrologic unit should be avoided because it can cause air entrainment, inhibiting future sampling efforts and possibly altering groundwater chemistry.

The air injected into the well should be filtered using an oil/air filter and oil trap to remove any compressor lubricant entrained in the air. Air pressures required for this well development method are relatively low; an air pressure of 14.8 pounds per square inch should move a 30-foot column of water. For small-diameter, shallow wells where the amount of development water is likely to be limited, tanks of inert gas (such as nitrogen) can be used as an alternative to compressed air.

2.1.4 Backwashing

Effective development procedures should cause flow reversals through the screen openings that will agitate the sediment, remove the finer fraction, and then rearrange the remaining formation particles. Backwashing overcomes the bridging that results from overpumping by allowing the water that is pumped to the top of the well to flow back through the submersible pump and out through the well screen. The backflow portion of the backwashing cycle breaks down bridging, and the inflow then moves the fine material toward the screen and into the well.

Some wells respond satisfactorily to backwashing techniques, but the surging effect is not vigorous enough to obtain maximum results in many cases.

A variation of backwashing may be effective in low-permeability formations. After the filter pack is installed on a monitoring well, clean water is circulated down the well casing, out through the well screen and filter pack, and up through the open borehole before the grout or bentonite seal is placed in the annulus. Flow rates should be controlled to prevent floating the filter pack. Because of the low hydraulic conductivity of the formation, negligible amounts of water will infiltrate into the formation. Immediately after this procedure, the bentonite seal should be installed, and the nonformation water should be pumped out of the well and filter pack.

2.1.5 Surge Bailing

Surge bailing can be an effective well development method in relatively clean, permeable formations where water flows freely into the borehole. A bailer made of stainless steel or polyvinyl chloride and slightly smaller than the well casing diameter is allowed to fall freely through the borehole until it strikes the groundwater surface. The contact of the bailer produces a downward force and causes water to flow outward through the well screen, breaking up bridging that has developed around the screen. As the bailer fills and is rapidly withdrawn from the well, the drawdown created causes fine particles to flow through the well screen and into the well. Subsequent bailing can remove these particles from the well. Lowering the bailer to the bottom of the well and using rapid short strokes to agitate and suspend solids that have settled to the well bottom can enhance removal of sand and fine particles. Bailing should continue until the water is free of suspended particles.

2.1.6 Well Jetting

Well jetting can be used to develop monitoring wells in both unconsolidated and consolidated formations. Water jetting can open fractures and remove drilling mud that has penetrated the aquifer. The discharge force of the jetting tool is concentrated over a small area of the well screen. As a result, the tool must be rotated constantly while it is raised and lowered in a very small increments to be sure that all portions of the screen are exposed to the jetting action.

Jetting is relatively ineffective on the fine screens typically used in monitoring wells (slot sizes from 0.01 to 0.02 inch). In addition, jetting requires the introduction of external water into the well and surrounding formation. This water should be obtained from a source of known chemistry. Water introduced for development should be completely removed from the aquifer immediately after development.

The use of compressed air as a jetting agent should not be employed for development of monitoring wells. Compressed air could entrain air in the formation, introduce oil into the formation, and damage the well screen.

2.2 FACTORS TO CONSIDER WHEN SELECTING A WELL DEVELOPMENT METHOD

It is important to check federal, state, and local regulatory requirements for monitoring well development requirements. This SOP may be changed to accommodate applicable regulations, site conditions, or equipment limitations.

The type of geologic material, the design and completion of the well, and the type of drilling method used are all factors to be considered during the development of a monitoring well.

Monitoring well development should usually be started slowly and gently and then performed with increasing vigor as the well is developed. Most well development methods require the application of sufficient energy to disturb the filter pack, thereby freeing fine particles and allowing them to be drawn into the well. The coarser particles then settle around and stabilize the screen.

Development procedures for wells completed in fine sand and silt strata should involve methods that are relatively gentle so that strata material will not be incorporated into the filter pack. Vigorous surging for development can produce mixing of the fine strata and filter pack and produce turbid samples from the formation. In addition, development methods should be carefully selected based upon the potential contaminants present, the quantity of wastewater generated, and requirements for containerization or treatment of wastewater.

For small diameter and small volume wells, a development bailer can be used in place of a submersible pump in the pumping method. Similarly, a bailer can be used in much the same fashion as a surge block in small diameter wells.

Any time an air compressor is used for well development, it should be equipped with an oil air filter or oil trap to minimize the introduction of oil into the screened area. The presence of oil could impact the organic constituent concentrations of the water samples collected from the well.

The presence of light nonaqueous phase liquid (LNAPL) can impact monitoring well development. Water jetting or vacuum-enhanced well development may assist in breaking down the smear zone in the LNAPL. Normal development procedures are conducted in the water-saturated zone and do not affect the LNAPL zone.

2.3 INITIATING WELL DEVELOPMENT

Newly completed monitoring wells should be developed as soon as practical, but no sooner than 24 hours after grouting is completed if rigorous well development methods are used. Development may be initiated shortly after well installation if the development method does not interfere with the grout seal. State and local regulations should be checked for guidance. The following general well development steps can be used with any of the methods described in Section 2.1.

1. Assemble the necessary equipment on a plastic sheet around the well. This may include a water level meter (or oil/water interface probe if LNAPL or dense nonaqueous phase liquid is present); personal protective equipment; pH, conductivity, temperature, and turbidity meters; air monitoring equipment; Well Development Data Sheets (see Figure 2); a watch; and a field logbook.

2. Open the well and take air monitoring readings at the top of the well casing and in the breathing zone. See SOP No. 003 (Organic Vapor Air Monitoring) for additional guidance.

3. Measure the depth to water and the total depth of the monitoring well. See SOP No. 014 (Static Water Level, Total Well Depth, and Immiscible Layer Measurement) for additional guidance.

4. Measure the initial pH, temperature, turbidity, and specific conductance of the groundwater from the first groundwater that comes out of the well. Note the time, initial color, clarity, and odor of the water. Record the results on a Well Development Data Sheet (see Figure 2) or in a field logbook. See SOPs No. 011 (Field Measurement of Water Temperature), 012 (Field Measurement of pH), 013 (Field Measurement of Specific Conductance), and 088 (Field Measurement of Water Turbidity) for additional guidance.

5. Develop the well using one or more of the methods described in Section 2.1 until the well is free of sediments and the groundwater turbidity has reached acceptable levels. Record the development method and other pertinent information on a Well Development Data Sheet see Figure 2) or in a field logbook.

6. Containerize any groundwater produced during well development if groundwater contamination is suspected. The containerized water should be sampled and analyzed to determine an appropriate disposal method.

7. Do not add water to assist in well development unless the water is from a source of known chemical quality and the addition has been approved by the project manager. If water is added, five times the amount of water introduced should be removed during development.

8. Continue to develop the well, repeating the water quality measurements for each borehole volume. Development should continue until each water quality parameter is stabile to within 10 percent. Development should also continue until all the water added during development (if any) is removed or the water has a turbidity of less than 50 nephelometric turbidity units. This level may only be attainable after allowing the well to settle and testing at low flow sampling rates.

9. At the completion of well development, measure the final pH, temperature, turbidity, and specific conductance of the groundwater. Note the color, clarity, and odor of the water. Record the results on a Well Development Data Sheet (see Figure 2) or in a field logbook. In addition to the final water quality parameters, the following data should be noted on the Well Development Data Sheet: well identification, date(s) of well installation, date(s) and time of well development, static water level before and after development, quantity of water removed and time of removal, type and capacity of pump or bailer used, and well development technique.

All contaminated water produced during development should be containerized in drums or storage vessels properly labeled with the date collected, generating address, well identification, and consultant contact number.

2.4 DURATION OF WELL DEVELOPMENT

Well development should continue until representative water, free of the drilling fluids, cuttings, or other materials introduced during well construction is obtained. When pH, temperature, turbidity, and specific conductance readings stabilize and the water is visually clear of suspended solids, the water is representative of formation water. The minimum duration of well development should vary in accordance with the method used to develop the well. For example, surging and pumping the well may provide a stable, sediment free sample in a matter of minutes, whereas bailing the well may require several hours of continuous effort to obtain a clear sample.

An on-site project geologist should make the final decision as to whether well development is complete. This decision should be documented on a Well Development Data Sheet (see Figure 2) or in a field logbook.

2.5 CALCULATIONS

It is necessary to calculate the volume of water in the well. Monitoring well diameters are typically 2, 3, 4, or 6 inches. The height of water column (in feet) in the well can be multiplied by the following conversion factors to calculate the volume of water in the well casing.

Well Diameter (inches)	Volume (gallon per foot)
2	0.1631
3	0.3670
4	0.6524
6	1.4680

3.0 POTENTIAL PROBLEMS

The following potential problems can occur during development of monitoring wells:

- In some wells the pH, temperature, and specific conductance may stabilize but the water remains turbid. When this occurs, the well may still contain construction materials (such as drilling mud in the form of a mud cake) and formation soils that have not been washed out of the borehole. Excessive or thick drilling muds cannot be flushed out of a borehole with one or two well volumes of flushing. Continuous flushing over a period of several days may be necessary to complete well development. If the well is completed in a silty zone, it may be necessary to sample with low flow methods or filtering.

- Mechanical surging and well jetting disturb the formation and filter pack more than other well development methods. In formations with high clay and silt contents, surging and jetting can cause the well screen to become clogged with fines. If an excessive amount of fines is produced, sand locking of the surge block may result. Well development with these methods should be initiated gently to minimize disturbance of the filter pack and to prevent damage to the well screen.

- Effective overpumping may involve the discharge of large amounts of groundwater. This method is not recommended when groundwater extracted during well development is contaminated with hazardous constituents. If the hazardous constituents are organic compounds, this problem can be partially overcome by passing the groundwater through an activated carbon filter.

- When a well is developed by mechanical surging or bailing, rapid withdrawal of the surge block or bailer can result in a large external pressure outside of the well. If the withdrawal is too rapid and this pressure is too great, the well casing or screen can collapse.

- A major disadvantage of well jetting is that an external supply of water is needed. The water added during well jetting may alter the hydrochemistry of the aquifer; therefore, the water added in this development procedure should be obtained from a source of known chemistry. In addition, the amount of water added during well development and the amount lost to the formation should be recorded.

- The use of air in well development can chemically alter the groundwater, either directly through chemical reaction or indirectly as a result of impurities introduced through the air stream. In addition, air entrainment within the formation can interfere with the flow of groundwater into the monitoring well. Consequently, air should not be injected in the immediate vicinity of the well screen.

FIGURE 1

SCHEMATIC DRAWING OF A SURGE BLOCK

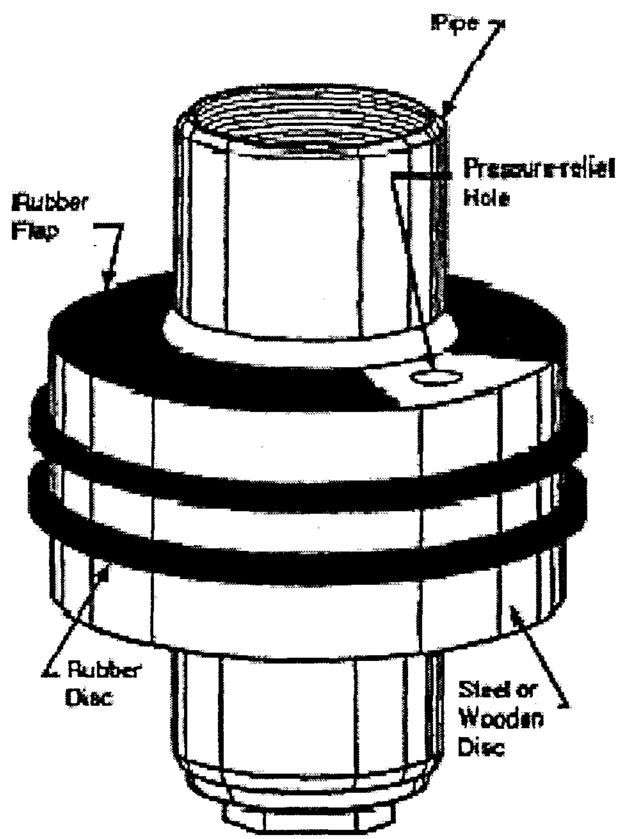

FIGURE 2

WELL DEVELOPMENT DATA SHEET

Sheet ___ of ___

WELL DEVELOPMENT DATA SHEET

BORING NO. __________ WELL NO. __________

Project ______________________________
Project No. ______________________________
Date(s) of Installation ______________________________
Date(s) of Development ______________________________
Personnel/Company ______________________________
____
Type of Rig Used ______________________________

Casing Diameter/Type ______________________________
Borehole Diameter ______________________________
Screened Interval(s) ______________________________
Total Length of Well Casing ______________________________
Measured Total Depth (TOC) Initial ______________
Final ______________
Initial Depth to Water
(TOC) ______________ Date __________ Time __________
Stabilized Depth to Water
(TOC) ______________ Date __________ Time __________

DEVELOPMENT TECHNIQUE(S) — EQUIPMENT TYPE/CAPACITY

___ Surging ______________________
___ Overpumping ______________________
___ Air Lift Pumping ______________________
___ Backwashing ______________________
___ Bailing ______________________
___ Well Jetting ______________________

FLUIDS ADDED

Lost Drilling Fluid: ______________ Gallons
Lost Purge Water: ______________ Gallons
Water During Installation: ______________ Gallons
Total Fluids Added: ______________ Gallons
Source of Added Water: ______________________
Sample Collected of Added Water: Y N
Sample Designation of Added Water: ______________________

PURGE VOLUME CALCULATION

Casing Volume: __________ Ft. of water
x __________ Gallons/Foot
= __________ Gallons per Single Casing Volume
Sand Pack Volume: __________ Ft. of Saturated Sand Pack
x __________ Gallons/Foot (borehole diameter)
= __________ Gallons (in borehole)
- __________ Gallons of Casing Volume
= __________ x 0.3 (Assuming porosity = 30%)
= __________ Gallons Within Sand Pack
Single Purge Volume: __________ Gallons (Casing Vol. + Sand Pack Vol. + Fluids Added)
Minimum Purge Volume: __________ Gallons
Actual Purge Volume: __________ Gallons
Volume Measured by: ______________________
Rate of Development ______ Gallons/Minute (Hour, Day)
Pumping Rate/Depth __________ @ _____ Ft. (Below Grd.)
Immiscible Phases Present: Y N Thickness __________

Development Criteria: ____

Total Volume Discharged	Rate of Discharge	Time	Temp	pH	Specific* Conductance	Turbidity (NTU)	D.O., Clarity, Odor, PID Readings, Other:

Development Completed at ____________________ Gallons Discharged. Date: __________ Time: __________

Personnel: ____
____

* Specific Conductance readings temperature compensated to 25°C, if not, report temperatures at which reading obtained.

DS.0314.15091

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TREASURE ISLAND
SSIC NO. 5090.3

APPENDIX C

SOP 010: GROUNDWATER SAMPLING

SOP APPROVAL FORM

TETRA TECH EM INC.

ENVIRONMENTAL STANDARD OPERATING PROCEDURE

GROUNDWATER SAMPLING

SOP NO. 010

REVISION NO. 3

Signed cover sheet on file	*February 19, 1993*
Quality Assurance Approved	Date

DS.0314.15091

1.0 BACKGROUND

Groundwater sampling may be required for a variety of reasons, such as examining potable or industrial water supplies, checking for and tracking contaminant plume movement in the vicinity of a land disposal or spill site, Resource Conservation and Recovery Act (RCRA) compliance monitoring, or examining a site where historical information is minimal or non-existent, but where it is thought groundwater may be contaminated.

Groundwater is usually sampled through an in-place well, either temporarily or permanently installed. However, it can also be sampled anywhere groundwater is present, such as a pit or a dug or drilled hole.

Occasionally, a well will not be in the preferred location to obtain the sample needed (for example, to track a contaminant plume). In such a case, a temporary or permanent well will have to be installed. An experienced and knowledgeable person, preferably a hydrogeologist, will need to locate the well and supervise its installation so that the samples ultimately collected will be representative of the groundwater.

1.1 PURPOSE

This standard operating procedure (SOP) establishes the requirements and procedure for determining the quality of groundwater entering, leaving, or affected by site activities through groundwater sampling. The samples are obtained by retrieving water from a well screened in the underlying aquifer(s) at a site.

1.2 SCOPE

This SOP applies to all groundwater sampling activities conducted in the field.

1.3 DEFINITIONS

Bailer - A cylindrical sampling device with valves on either end used to extract water from a well. Bailers are usually constructed of an inert material such as stainless steel or polytetrafluoroethylene (Teflon). The bailer is lowered and raised by means of a cable that may be cleaned and reused, or by disposable rope.

Electrical Water Level Indicator - An electrical device that has a light or sound alarm connected to an open circuit used to determine the depth to fluid. The circuit is closed when the probe intersects a conducting fluid. The wire used to raise and lower the probe is usually graduated.

Immiscible Phase - Liquid phases that cannot be uniformly mixed or blended with water. Heavy immiscible phases sink, and light immiscible phases float on water.

Interface Probe - An electrical probe that determines the distance from the surface to air/water, air/immiscible, or immiscible/water interfaces.

Purge Volume - The volume of water that needs to be removed from the well to ensure that a sample representative of the groundwater is taken.

Riser Pipe - The length of well casing above the ground surface.

Total Well Depth - The distance from the ground surface to the bottom of the well.

Water Level - The level of water in a well. Measured as depth to water or as elevation of water, relative to a reference mark or datum.

1.4 REFERENCES

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1.5 REQUIREMENTS AND RESOURCES

There are various options available to obtain groundwater samples. The procedures are outlined in the following section. The equipment needed to accomplish these procedures includes the following:

- Organic vapor detector with a flame ionization detector (FID) or a photoionization detector (PID)
- Pipe wrench
- Electrical water level indicator or interface probe

- Steel tape with heavy weight
- Purging device (type needed depends on well depth, casing diameter, type of sample desired - see sampling devices below)
- Sampling device (type needed depends upon depth to water and type of sample desired)
  - Teflon bailer
  - Stainless steel bailer
  - Teflon bladder pump
  - Stainless steel submersible (nonoil-bearing) pump
  - Existing dedicated equipment
  - Peristaltic pump
- Sample containers
- Wastewater containers
- Field logbook
- Stopwatch

Additional equipment is required to complete measurement of field parameters (i.e., pH, specific conductance, and temperature) of the groundwater at the well.

2.0 PROCEDURE

Prior to sampling, a site-specific sampling plan should be developed. The plan should take into consideration the site characteristics and should include:

- The specific repeatable well measurement techniques and reference points for determining the depth to water and the depth to the bottom of the well
- The specific method of purging and selection of purging equipment
- The specific analytic method for measurements of field parameters and the selection of field analytical equipment
- The specific method of sample collection and selection of sampling equipment
- The order of sample bottle filling
- The sample chemical analytical parameters

The following sections discuss procedures for approaching the well, establishing a sample preparation area, preliminary well measurements, purging the well, and sample collection.

2.1 APPROACHING THE WELL

In general, all wells should be assumed to pose a health and safety risk until field measurements indicate otherwise. Approach wells from the upwind side. Record well appearance and general condition of the protective casing, surface seal, and surrounding area in the logbook.

Once at the well, the lead person should systematically use the organic vapor detector to survey the immediate area around the well (from the breathing zone to the top of the casing to the ground). If elevated FID and PID meter readings are encountered, retreat to a safe area and instruct the sampling team to put on the appropriate level of personal protective equipment (PPE).

Upon opening the well casing, the lead person should systematically survey inside the well casing, above the well casing in the breathing zone and the immediate area around the well. If elevated FID or PID meter readings in the breathing zone are encountered (see health and safety plan for action levels), retreat and put on appropriate PPE. It is important to remember that action levels are based on readings in the breathing zone, not within the well casing. Representative organic vapor detector readings will be recorded in the logbook.

2.2 ESTABLISHING A SAMPLE PREPARATION AREA

The sample preparation area is generally located upwind or to either side of the well. If elevated readings are encountered using an organic vapor detector, this area should be taped off and the sample preparation area should be located upwind where ambient readings are found.

2.3 PRELIMINARY WELL MEASUREMENTS

Several preliminary well measurements should be made prior to initiating sampling of the well. These include determining water level and total well depth measurements, determining the presence of immiscible phases, and calculating purge volumes. All preliminary measurements will be recorded in the logbook as they are determined.

2.3.1 Water Level and Total Well Depth Measurements

Tetra Tech typically uses an electric water-level indicator for water level measurements. This device sounds an alarm or illuminates a light when the measuring probe touches the water surface, thus closing an electrical circuit. The electric cable supporting the probe is usually graduated in feet and can be read at the well site directly. The remaining fraction is measured with a steel tape graduated to 0.01 foot. The distance between the static water level and the marked or notched location at the top of the riser pipe is measured. The height of the riser pipe above ground surface, as obtained from well location survey data, is then subtracted from the total reading to give the depth to static water. To improve the accuracy of the readings, each measurement should be for a series of three readings, and the values averaged. This helps to eliminate any errors due to kinks or bends in the wires, which may change the length when the device is raised and lowered.

The total well depth can be measured by using a steel tape with a heavy weight attached to the end. The tape is lowered into the well until resistance is met, indicating that the weight has reached the bottom of the well. The total well depth is then read directly from the steel tape to the 0.01-foot fraction. The distance between the bottom of the well and the marked or notched location on the riser pipe is measured. The height of the riser pipe above the ground surface, as obtained from well survey data, is then subtracted from the total reading to give the depth to the bottom of the well. To improve the accuracy of the readings, the weighted steel tape should be used to rapidly make a series of three readings, and the readings averaged.

2.3.2 Determining If Immiscible Phases Are Present

If immiscible phases (organic floaters or sinkers) are present, the following measurement activities should be undertaken. Organic liquids are measured by lowering an interface probe slowly to the surface of the liquid in the well. When the audible alarm sounds, record the depth. If the alarm is continuous, a floating immiscible layer has been detected. To determine the thickness of this layer, continue lowering the probe until the alarm changes to an oscillating signal. The oscillating signal indicates that the probe has detected an aqueous layer. Record this depth as the depth to water and determine the thickness and the volume of the immiscible layer.

Continue lowering the probe into the well to determine if immiscible dense phases (sinkers) are present. If the alarm signal changes from oscillating to a continuous sound, a heavier immiscible layer has been detected; record this depth.

Continue lowering the probe to the bottom of the well and record the total depth. Separate total depth measurements with a steel tape are not necessary when using an interface probe. Calculate and record the sinker phase volume and total water volume in the well. A chart is provided in Table 1 to assist in these calculations. If immiscible phases are present, immediately refer to Section 2.5.1 or 2.5.2 of this SOP.

TABLE 1

LIQUID VOLUME IN A 1-FOOT SECTION OF WELL CASING

Well Casing Inside Diameter (D) (inches)	Volume of Liquid in 1-Foot Well Section (gallons) $V= 0.0408 (D^2)$
1	0.041
1.5	0.092
2	0.163
3	0.367
4	0.653

2.3.3 Determination of Purging Volume

If the presence of floaters or sinkers does not need to be determined, determine the depth to water and the total depth of the well as described in Section 2.3.1. Once these measurements have been made and recorded, use Table 1 to calculate the total volume of water in the well. Multiply this volume by the purging factor to determine purging volume. The minimum purging factor is three casing volumes but may be superseded by site-specific program requirements, individual well yield characteristics, or stabilization of field parameters measured during purging. Field parameters (i.e., pH, specific conductance, and temperature) should be measured prior to purging and after each well volume. All field parameter data are recorded in the field logbook.

In Table 1, the volume of water in a 1-foot section of a 2-inch-diameter well is 0.16 gallon. This chart can easily be used for any water depth by multiplying all the values in Table 1 by the L value (depth, in feet, of water in the well).

The volume of water in the well is based on the following formula:

$$V = \frac{\pi \text{ x } D^2}{4} \text{ x } L$$

where

V = volume of water in the well (cubic feet)

D = inside diameter of the well (feet)

L = depth of water in the well (feet)

2.4 PURGING THE WELL

Currently, Tetra Tech standards allow for six options for purging wells:

1. Teflon bailers
2. Stainless steel bailers
3. Teflon bladder pumps
4. Stainless steel submersible (nonoil-bearing) pumps
5. Existing dedicated equipment (use of these devices must be approved by on-site client representatives)
6. Peristaltic pumps (these devices are for shallow wells only and must be approved by the on-site client representative)

As previously stated, the established minimum purging volume is three casing volumes. The exception to this standard is in the case of low-yield wells. When purging low-yield wells, purge the well once to dryness. Samples should be collected as soon as the well recovers. When the time required for full recovery exceeds 3 hours, samples should be collected as soon as sufficient volume is available.

The well should be purged until the measured field parameters have been stabilized. If any field parameter has not stabilized, additional purging should be performed. To be considered stable, field parameters should change by no more than the tolerance levels listed on Table 2 between each well volume purged.

TABLE 2

FIELD MEASUREMENT TOLERANCE LEVELS

Field Parameter	Tolerance Level
PH	0.1 pH unit
Specific Conductance	10 percent relative percent difference (RPD)
Temperature	1 °C

At no time should the purging rate be high enough to cause the groundwater to cascade back into the well, resulting in excessive aeration and potential stripping of volatile constituents.

The actual volume of purged water can be measured using several acceptable methods:

- When bailers are used, the actual volume of each bailer's contents can be measured using a calibrated bucket.
- If a pump is used for purging, the pump rate can be determined by using a bucket of known volume, stopwatch, and the duration of pumping time necessary to purge the known volume.

2.5 SAMPLE COLLECTION

The technique used to withdraw a groundwater sample from a well should be selected based on the parameters for which the sample will be analyzed. To ensure that the groundwater samples are representative, it is important to avoid physically altering or chemically contaminating the sample during collection, withdrawal, or containerization. If the samples are to be analyzed for volatile organic compounds, it is critical that air does not become entrained in the water column.

Acceptable sampling devices for all parameters are double check valve stainless steel or Teflon bailers, bladder pumps, low-flow positive displacement pumps, or for shallow wells, peristaltic pumps. Additional measurements of field parameters should be performed at the time of sampling.

In some cases, it may become necessary to use dedicated equipment already in the well to collect samples. This is particularly true of high volume, deep wells (>150 feet) where bladder pumps are ineffective and bailing is impractical. If existing equipment must be used, however, determine the make and model of the pump and obtain information on component construction materials from the manufacturer or facility representatives. If an existing pump is to be used for sampling, make sure the flow volume can be reduced so that a reliable volatile organics analysis (VOA) sample can be taken. Record which specific port, tap, or valve the sample is collected from.

General sampling procedures include the following:

- Clean sampling equipment should not be placed directly on the ground. Use a plastic drop cloth or feed line from clean reels. Never place contaminated lines back on reels.
- Check the operation of the bailer check valve assemblies to confirm free operation.
- If the bailer cable is to be decontaminated and reused, it must be made of Teflon-coated stainless steel.
- Lower sampling equipment slowly into the well to avoid degassing the water and damaging the equipment.
- Pump flow rates should be adjusted to eliminate intermittent or pulsed flow. The settings should be determined during the purging operations.
- A separate sample volume should be collected to measure necessary field parameters. Samples should be collected and containerized in the order of the parameters' volatilization sensitivity. Table 3 lists the preferred collection order for some common groundwater parameters.

TABLE 3

ORDER OF PREFERRED SAMPLE COLLECTION

1. VOA
2. Purgeable organic halogens (POX)
3. Total organic halogens (TOX)
4. Cyanide
5. Extractable organics
6. Purgeable organic carbon (POC)
7. Total metals
8. Dissolved metals
9. Total organic carbon (TOC)
10. Phenols
11. Sulfate and chloride
12. Nitrate and ammonia
13. Radionuclides

Intermediate containers should never be used to prepare VOA samples and should be avoided for all parameters in general. All VOA containers should be filled at a single sampling point or from a single bailer volume.

2.5.1 Collection of Light Immiscible Floaters

The approach used when collecting floaters is dependent on the depth to the floating layer and the thickness of that layer. If the thickness of the floater is 2 feet or greater, a bottom-filling valve bailer should be used. Slowly lower the bailer until contact is made with the floater surface, and lower the bailer to a depth less than that of the floater/water interface depth as determined by preliminary measurements with the interface probe.

When the thickness of the floating layer is less than 2 feet, and the depth to the surface of the floating layer is less than 15 feet, a peristaltic pump can be used to extract a sample.

When the thickness of the floating layer, however, is less than 2 feet and the depth to the surface of the floating layer is beyond the effective "lift" of a peristaltic pump (greater than 25 feet), a bailer can be modified to allow filling from the top only (an acceptable alternative is to use a top- loading Teflon or stainless-steel bailer). Disassemble the bailer's bottom check valve and insert a piece of 2-inch diameter Teflon sheet between the ball and ball seat. This will seal off the bottom valve. Remove the ball from the top check valve, thus allowing the sample to enter from the top. To overcome buoyancy when the bailer is lowered into the floater, place a length of one-inch stainless steel pipe on the retrieval line above the bailer (this pipe may have to be notched to allow sample entry if the pipe remains within the top of the bailer).

Or, as an alternative, use a top-loading stainless-steel bailer. Lower the device, carefully measuring the depth to the surface of the floating layer, until the top of the bailer is level with the top of the floating layer. Lower the bailer an additional one-half thickness of the floating layer and collect the sample. This technique is the most effective method of collection if the floating layer is only a few inches thick.

2.5.2 Collection of Heavy Immiscible Sinkers

The best method for collection of sinkers is use of a double check valve bailer. The key to collection is controlled, slow lowering and raising of the bailer to and from the bottom of the well. Collection methods are equivalent to those described in Section 2.5.1 above. Note that both floaters and sinkers must be collected prior to any purging activities.

2.5.3 Collection of Volatile Organics Samples

This section discusses the collection of samples for VOA using either a bailer or bladder pump in detail. Other pumps (such as positive displacement or peristaltic) can be used. Critical to the collection of representative samples for VOA are ensuring that no air has become entrained in the water column, low pump flow rates (less than 100 milliliter [mL] per minute, if possible), and avoiding flow surges.

2.5.3.1 Collection with Bailers

Samples for VOA should be collected from the first bailer removed from the well after purging. The most effective means requires two people. One person should retrieve the bailer from the well and pour its contents into the appropriate number of 40-mL VOA vials held by the second person. Cap each vial and invert it. If a bubble exists, unscrew the cap and add more water, or discard and repeat. The sample is transferred from the bailer to the sample container in a manner that will limit the amount of agitation in order to reduce the loss of volatile organics from the sample.

Always fill VOA vials from a single bailer volume. If the bailer is refilled, samples cannot be considered duplicates or splits.

2.5.3.2 Collection with a Bladder Pump (Well Wizard)

To successfully perform VOA sampling with a Well Wizard bladder pump, the following steps must be completed:

1. Following manufacturer's directions, activate the Well Wizard pump. Full water flow from the discharge tubing will begin after 5 to 15 pumping cycles. These initial pumping cycles are required to purge air from the pump and discharge tubing. The discharge and recharge settings must be manually set and adjusted to pump at optimum flow rates. To activate the bladder, it is best to set the initial cycle at long discharge and recharge rates.

2. Reduce water flow rate for VOA sample collection. To reduce the water flow rate, turn the throttle control valve (located on the left side of the Well Wizard pump control panel) counterclockwise.

3. Collect VOA sample from discharge tubing. VOA vials must be placed beneath the discharge tubing while avoiding direct contact between the vials and the tubing. Never place tubing past the mouth of the VOA vial. The pump throttle control must be turned as necessary to maintain a trickle of water in order to obtain a meniscus in the vial.

4. Continue with non-VOA sampling. Increase pump flow rate by turning the throttle control knob clockwise.